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GROWING TREES FOR FOREST PLANTING IN MONTANA AND IDAHO

By

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CHIEF OF PLANTING, REGION 1
FOREST SERVICE

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PREFACE

The following text gives essential information on the selection and development of a nursery site, on soil management, and on storage of seed, with examples drawn from the Savenac nursery of the Forest Service at Haugan, Mont. It describes the propagation and care of evergreens at Savenac nursery, and the distribution of the planting stock produced there. It also describes implements specially devised for this kind of work. Little things, knacks of the trade as they are called, and the organization of the work are included.

Methods that have been developed for this particular nursery may not be directly applicable to all nurseries, because of differences in climate, soil, and number or kind of trees raised. However, they may be used in part or adapted to fit conditions at other nurseries.

THE NURSERY SITE

SELECTION

The site of a forest-tree nursery should be within the region in which the trees are to be planted, and its climate should be typical of the climate in the region as a whole. Extremes in altitude should be avoided. If these precautions are taken in choosing the nursery site there will be little difficulty in raising at the nursery the species

best suited to the region to be served. Furthermore, the growing seasons at the nursery and on the planting sites will nearly coincide so that conditions will be favorable for the planting at the same time that they are best for removing the stock from the nursery. If these precautions are not taken and if the trees have to be kept in the nursery long after they start growth in the spring because the planting site is not ready, the trees will suffer severe injury upon removal, and the loss will be heavy. If, in order to avoid this loss, the trees are removed from the nursery and placed in snow pits at the planting site so that spring growth will be retarded until the planting site is ready, the extra handling will increase the expense (p. 81). If the planting site is ready long before the nursery ground can be worked, the planting site may become too dry for satisfactory planting by the time the nursery stock can be moved.

The problem of the planting site being ready before the nursery ground could be worked was encountered by Fetherolf[1] at the Beaver Creek nursery in Utah, and was solved by broadcasting fine black soil on the snow over the compartments from which stock was

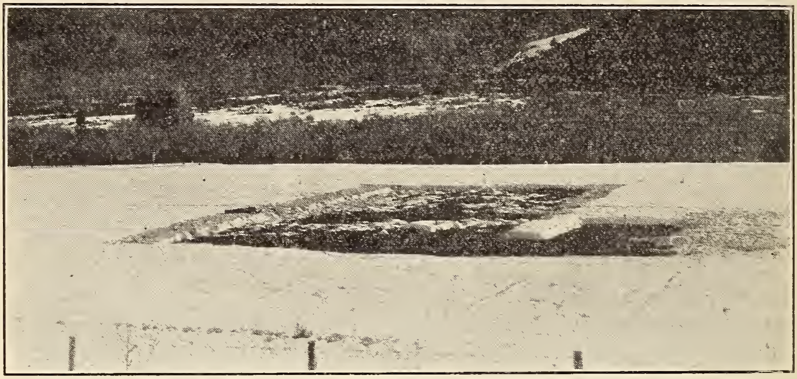

FIGURE 1.—Snow removal by broadcast soil. Beaver Creek Nursery, Utah

to be removed first. Heat absorbed by the black soil particles hastened the melting of the snow, and he was able to get out his shipping stock two weeks earlier than would otherwise have been possible and to have the trees at the early planting sites when conditions were favorable. (Fig. 1.) If a fresh snowfall covered the soil the first treatment became useless, and another application was necessary. However, this rarely occurred because the snow to be removed was the last foot or two of the winter's accumulation remaining late in the spring.

A coniferous nursery requires abundant water well distributed throughout the growing season. In most regions artificial watering must be depended upon. The supply must be sufficient when at its lowest stage, because that stage is reached in the driest period of the summer (July and August), when the demand for water is greatest. Even where natural rainfall is commonly abundant through the growing season, some means of artificial watering should

[1] FETHEROLF, J. M. 1917. Unpublished manuscript.

be provided as an auxiliary to the natural supply, to make it possible to water the new seed beds lightly every day, and to be used in case of a deficiency in rainfall.

Level land is more easily cultivated and irrigated than rolling land. Rough ground should be avoided if the top soil is shallow, because if the land has to be leveled rock and gravel will be uncovered in scraping off the knolls to fill the depressions.

The ground should be well drained.

For propagating coniferous seedlings and young transplants for forest planting stock light sandy loam is better than heavy soils. Light soil is easily worked. Fibrous root systems develop more readily in fine-textured soils. The tree stems rise through the light soil individually without causing long cracks in the surface. The soil does not bake and crack, exposing the tender embryos just breaking through the seed coats. Surface drainage is better and consequently conditions are less favorable to nursery diseases.

Heavy clay is preferred by some nurserymen for propagating ornamental evergreens grown a foot or more in height. The heavy soil adheres to the roots so that each tree can be removed with a ball of earth and burlapped in that manner for shipment. Forest-tree planting stock is seldom shipped with these balls of earth attached.

A location should be chosen where there is contiguous ground which may be annexed to the nursery if needed, and which may readily be served by the same irrigation system. A larger scale of production may make more land a necessity later, and adjustments to more liberal plans of rotation may make it very desirable. Adjustments in nursery practice, such as growing older age classes and using wider spacing, may require more area. Patches of ground later found unsuited for nursery work, or at best expensive to use, can be abandoned for better ground.

A square piece of ground is more desirable than a long narrow strip, because buildings and other improvements can be more advantageously grouped to serve the entire nursery.

It is also well to choose if possible a nursery site with a readily available source of packing material such as a pond with sphagnum moss or a shingle mill near by from which shingle tow may be gotten, a deposit of sand for seed-bed covering, and timber for fuel.

The neighborhood of each site should be examined to determine the presence or relative abundance of the alternate hosts of the stem rusts which may infect the nursery stock, and of certain other tree diseases. If two sites are of equal desirability in other ways, the one having the less evidence of disease or the fewer disease carriers in its vicinity should be chosen.

GROUND PLAN

The nursery should be definitely divided into a convenient number of compartments, to facilitate the handling of crop rotations, the planning of permanent improvements, and record keeping. The record keeping needs emphasis. A history should be kept of all treatments given the soil, of all crops grown on the soil, and of the rest periods that follow the crops, in order that soil management may be intelligently practiced, and past treatments reviewed when

differences in the thriftiness of stock are noted. At Savenac a map is prepared each spring showing the compartments under cultivation and those lying idle; the species, the age classes, and densities in each compartment; and the kind of treatment given the soil. This map serves as a current office record of the stock in the nursery and also as a permanent record of soil management. Orderly rotation and clearly defined compartments are necessary to such record keeeping. So far as practical these compartments should be rectangular. As a matter of fact the general nursery plan should be designed in rectangles, not only to improve working conditions but for appearance. The hundreds of uniform beds, straight rows, and clearly defined paths, which are pleasing to the eye, will be even more pleasing when the compartments and yards have the same geometrical form. Natural landscaping is out of the question in a nursery; formal gardening is appropriate.

Roads are needed through the nursery. It is best to determine those of primary importance and make them permanent from the start. These should be parallel to the edges of the beds to conform to the general ground plan. Secondary roads, roads which may be needed to reach certain parts of the nursery in one year and not in another, may be merely blank strips left in the compartment between seed beds or transplant rows, and later plowed at the same time that the ground on either side is plowed.

The entire nursery should be inclosed with good, substantial fencing. Seed-bed areas should be especially well guarded against trampling by animals. Hog-wire fencing will exclude dogs, sheep, and animals of like size, but is no hindrance to rabbits.

Hedges are attractive, but their use should be confined to the outer limits of the nursery, or the yards, and they should not be placed between the compartments, unless they are needed as windbreaks to protect the young nursery stock. Fencing between the compartments doubles the idle ground used only for turning room, which is bad enough, but hedges in addition draw heavily upon the soil far into the compartments.

Ornamental planting about the nursery grounds should be encouraged. Whether ornamental or forest-tree stock is being propagated the public expects to see well-kept grounds and a display of planted trees and shrubs. Especially if only 2-year-old and 3-year-old forest trees are being produced, older specimens should be grown about the lawns or on the borders of the nursery to show the more easily recognized form characteristics of the different species.

BUILDINGS

The number and kind of buildings that will be required to conduct the work properly depends, of course, upon the size and location of the nursery. Forest nurseries are naturally situated in outlying districts, far removed from centers of supplies, labor markets, and shops; and consequently must be equipped to carry on the work independently. Buildings for the men, buildings for supplies, and shops well equipped with tools become necessary in addition to those common to all nurseries.

The following are the buildings required at Savenac nursery. There are a number of other buildings used by the forest ranger

and the man engaged in planting and nursery research work that have been added as a matter of convenience and economy, but these do not affect the nursery work.

Residence for nursery superintendent, a building suitable for his yearlong needs.

Office and small laboratory.

Four bunk houses, each 18 by 24 feet, partitioned off into a living room and bedroom; one story; capacity, 12 men. Each building equipped with three steel double-deck bunks, washbowls, heater, electric lights, and individual lockers. These buildings are not used in winter; consequently they are of light construction suitable for habitation only in mild weather.

Dining hall, a story and a half building with kitchen wing; dining room 24 by 24 feet; kitchen spacious and fully equipped, including refrigerator and hot and cold water; upstairs divided into cook's room, bathroom, and commissary.

Bathhouse, one story; concrete floor; 18 by 24 feet; equipped with toilets, shower baths, laundry tubs, and hot-water heater.

Barn, stalls for nursery team, nurseryman's family cow, and three extra stalls for hired horses; hayloft, for storage of winter's supply of hay.

Warehouse, floor space 20 by 38 feet; one story, with lean-to full length on one side. Includes woodworking shop fully equipped with common woodworking tools, machine bench, machine tools, and post drill. One section contains racks of pipe fittings and tools to cut and thread pipe. Hand tools, hose, transplant boards, rakes, shovels, and other garden tools, as well as supplies of burlap, canvas, and lumber are stored in this building. The lean-to shelters the blacksmith forge, pipe, and miscellaneous machinery.

Garage and implement shed combined.

Several woodsheds, a small ice house, and a root cellar complete the list of buildings needed for the nursery work.

A small greenhouse, which is used for experimental work, and a seed-extraction plant aid the nursery work to a certain extent, but are not part of the nursery improvements.

Screen frames and lath shade are stacked in the open. Moss and shingle tow are also left outside. The seed supply is stored under fairly constant moderate temperature, and where there is little danger of fire. Suitable conditions for storing the seed are found in the basement of the office building and in the warehouse.

IRRIGATION AND DRAINAGE

In making plans for an irrigation system there are two very important things to be considered: (1) the total supply of water available during the peak of the summer drought, when artificial watering must be resorted to; and (2) future expansion which may require an extension of the system.

Seed-bed compartments should be supplied with water under pressure because sprinklers give a uniform distribution and the amounts can be accurately gaged. This control of water is especially important on new seed beds where germinating seedlings require light and frequent watering. Where the ground is used interchangeably for seed beds and transplants the type of system is fixed by the requirements of the seed beds.

If the water costs nothing and plenty is available, then the cost of the system and cost of applying the water are of primary importance. Open irrigation is perhaps a cheaper method of watering than by means of closed carriers. The initial cost of the system is certainly less. However, enormous quantities of water are wasted by the open-ditch method.

Weed seeds collect in irrigation ditches which pass through idle fields. Also seeds accumulate from the rank growth that follows the course of the ditch. The water may be teeming with new weed life when it is distributed on the nursery compartments below. This is one disadvantage of open irrigation. Closed carriers protect the water, but if it is drawn from a pond or creek catching seed from a vastly greater area there is little reduction of the amount of weed seeds that will reach the nursery. However, it is feasible to bar the way for weed seeds by using charcoal or sand filtration beds at the intake of the water supply, if the water is inclosed from that point to its numerous outlets.

The amount of ground required for the network of ditches is another undesirable feature in open irrigation. A strip of ground 12 to 18 inches wide is required for each of the numerous small irrigation furrows dispensing water to the trees. Large ditches, the feeders, require from 3 to 4 feet of ground, and in addition a 6-foot strip on one or both sides is needed for turning room for horses with implements working up to the ditches.

The capacity of the main carrier should be large enough so that future growth of the nursery may be met by extending the system without necessitating complete reconstruction. The labor cost of installing a carrier, whether buried pipe, flume, or ditch, is about the same for one volume of flow as another. Costs of materials do not increase proportionately to volume either. Two-inch pipe costs approximately twice as much as one-inch pipe; yet the larger pipe will carry four times the volume of the small one—and other sizes in about the same proportion.

An ideal water system would consist of one main carrier for all irrigation and domestic purposes, buried below the frost line and tapped with gate valves at each compartment for overhead sprinkling and furrow irrigation alike. Weed seed could be eliminated from the water by a sand or charcoal filtration bed at the intake. An interchange of compartments for transplants and seedlings could be provided. An underground conveyance would simplify cultivation and release much ground otherwise needed for ditches and fluming. The same system could be used to supply water to the buildings, to fire hydrants, and for a small hydroelectric plant to generate power for lights. If the size of the pipe is gradually reduced from the intake, the pressure at the lower end is not appreciably reduced when water is being drawn above.

PIPE SYSTEMS

At Savenac nursery the network of pipes distributing water over the seed beds lies on the surface of the ground, in the paths. These pipes are placed in position after the beds have been sowed and are removed when the stock has completed development, to clear the way for digging implements. Surface pipes do not interfere with the work of weeding and the other ordinary care given to the seed beds in the time intervening. Soiling crops sown on vacant compartments are watered from a few irrigation furrows scratched over the ground to the nearest faucets. Water is shut off in the fall and the pipes disconnected, drained, and stacked. It is a surprising thing, that inch pipes left out over winter have bent under the

weight of snow to conform to the irregularities in the surface of the ground.

Sections of the system are readily disconnected by unions, a fitting that permits of pipes being disconnected without turning them.

Each sprinkling unit is operated independently by means of a gate-valve connection to the main pipe line.

The laterals are placed 100 feet apart and the space between reaches halfway from either side with the standard 50-foot hose lengths. Hose bibbs are fitted every 20 feet on pipe. Five-eighths inch hose is large enough for most sprinklers. Fittings are attached for ¾-inch hose bibbs.

Any number of sprinklers can be run at one time provided the size of the pipe is reduced as it extends farther and farther away. from the main supply line. The volumes of different-sized pipes are to each other as the squares of their diameters. That is, a 2-inch pipe carries four times as much water as a 1-inch pipe; a 3-inch pipe will supply nine 1-inch pipes, etc. However, a pipe line must be full in order to maintain its head pressure. Although a 2-inch pipe may supply 15 sprinklers, the volume in the pipe will be so reduced at the end of the line that the farthermost sprinklers will scarcely throw water at all. The pressure can be maintained through such a battery of sprinklers by running the first five sprinklers from a 2-inch pipe, then reducing to 1½-inch pipe for the next five, and using 1-inch pipe for the remainder.

Perforated sprinkling pipes have been tried at Savenac and found to be impractical with the water used there. The fine perforations become clogged with the numerous impurities contained in the water. For the same reason, the perforated types of lawn sprinklers are not satisfactory. The cast lawn sprinklers having one or a pair of nozzles a quarter-inch in diameter have been found very satisfactory. The large openings allow free passage of common foreign matter in the water, and yet the spray from some types is not coarse but because of provisions made in their construction, is thrown off like mist over a large area.

Systems of overhead pipes supported on posts are used in many nurseries. This plan is not considered practical in regions of heavy snowfall, because, unless the pipes are supported at short intervals, or dismantled each fall they will bend under the weight of snow. Frequent supports are, of course, a hindrance to work with horses in the compartments. Furthermore, the posts are a permanent fixture and therefore necessary on all the compartments whether in stock or idle for the time being.

Obstructions are not entirely eliminated by burying all pipe, because the connections to the surface are more or less in the way. The surface system is easily shifted, so that it is necessary to invest only in piping neeeded for the compartments growing stock, whereas, if a permanent distributing system is laid underground, the idle compartments as well must have the full equipment of water pipe.

FURROW IRRIGATION

For furrow irrigation the ground surface must be even, and the ditches must have so slight a gradient that the water barely flows; otherwise serious damage will result from soil washing. The trans-

plant fields at Savenac nursery are watered with irrigation furrows. The main carrier extends the full length of the transplant area on one side. Permanently installed flumes tap this ditch and extend across the upper end of each compartment. Half-inch holes are bored in the flumes to supply the water required in each furrow. Temporary furrows are placed between every five rows of transplants. The job of watering the compartments is simple and requires little time. Water is turned on in the evening, and in 24 hours the ground all over the transplant field is uniformly moist.

DRAINAGE

Boggy places and land subject to spring overflow should ordinarily be avoided. Unless drained, such land can not be satisfactorily worked in early spring, and is subject to damaging frost heaving when the saturated soil freezes.

Occasionally a piece of boggy ground may have special value to the nursery and warrant measures to drain it. At Savenac nursery two pieces of ground were subject to overflow and underground seepage from backwater in the creek. Both pieces of ground had especially good soil, and both were needed to round out otherwise irregular compartments difficult to work. By clearing the creek of logs and bowlders that were choking its channel and causing the backwater, natural drainage was improved to such an extent as to make the ground suitable for transplants.

Drainage can be improved by a number of open ditches or by buried draintile pipe to carry away excessive moisture. Open ditches are less desirable because they require more maintenace, collect débris, and interfere with work on the area. The additional expense of installing the tile system above that for putting in the open ditches is only the cost of the tile.

SOIL MANAGEMENT

Each nursery has its particular problems in soil management. The soil must be kept in good chemical and physical condition and its productivity must be maintained. Therein lies one of the most important responsibilities of the nurseryman. He must at no time permit his vigilance to lag in meeting this responsibility. Where coniferous seedlings are grown 50 or more to a square foot for several successive years the drain on soil is excessive; consequently there must be crop rotations and frequent fertilization. It often happens that nurseries reach the height of their potential performance only to find the soil badly run down.

Soil exhaustion, in the true sense of the term as used by agronomists, is not possible for virgin soil during any comparatively short period, but intensive cropping may remove readily available nutrient at a faster rate than they naturally become available from soil reserves by the gradual processes of weathering. Such a condition becomes manifest by much the same symptoms as those of soil exhaustion. The obvious remedy is either a reduction in the intensity of cropping or an increase in the use of fertilizer.

The history of forest-nursery practice in older countries indicates that in the long run soil fertility can not be maintained by the

simple policy of crop rotation and the use of leguminous cover crops. Either animal manures or commercial fertilizers, and possibly both, must be added, depending upon the physical and chemical requirements of the soil.

The chemical requirements are more easily supplied to the soil than organic matter. Bulky manures are seldom locally available in adequate amounts at reasonable expense. Commercial fertilizers alone do not meet the situation because they contain very little organic matter, while chemical fertilizers are entirely without it.

The upbuilding of humus is often neglected, either because of the expense of obtaining organic matter, or because of failure to understand its importance. Coniferous seedling culture returns nothing to the soil. It leaves no stubble, no leaf mold, and very few roots to build up the humus. Intensive cultivation in the nursery does not even permit weeds to lie on the ground and return their vegetative matter to the soil.

Crop rotation in its true meaning is not practiced in coniferous nurseries. There is no diversified cropping, for production is limited to one class of plants. Whether white pine or spruce is raised on the ground makes little difference to the soil because in the nursery the root systems are controlled, and they therefore feed in practically the same soil layer. What is actually meant by rotation in the nursery is that intensive cropping on the seed-bed areas may be lessened by rotating with transplants; and if compartments are left in summer fallow at regular intervals available plant food accumulates through the process of weathering.

Volumes have been written about fertilizers and their relation to the common problems of soil cropping. It is futile to attempt to discuss the subject fully in this bulletin. Furthermore, no formulas can be determined for stabilizing the chemical and physical condition of the soil because annual cropping and leaching are forever drawing upon the soil in varying degrees. The nurseryman should not attempt fine adjustments in soil fertility, but he can maintain a reasonably high standard of productiveness in the nursery by adding to the soil the proper constituents. With a knowledge of the value of various fertilizers, his best guide is an understanding of changing conditions in the nursery soil, gained during years of experience, so that he has actual instead of theoretical comparisons to make of soil productivity.

Soil management at Savenac is summed up as follows: Cover crops, or green manures, as they are often called, are grown on each compartment following the removal of a crop of trees. This is the cheapest expedient known for renewing soil fertility. However, the treatment is not commensurate with the drain. After the soiling crop, any land not reverted immediately to trees lies fallow for a year, which means that the soil rests. Fallow ground is ordinarily plowed a number of times to mellow the soil and to turn the weed crop back into the soil. The remaining deficiency in organic matter can be made up only by the complete use of all weeds and other vegetative litter that may be readily gathered about the nursery and composted with the stable manure from the nursery barn. Even then it becomes necessary to import occasionally a carload of manure to complete the treatment. Commercial ferti-

lizers are added to complete the chemical requirements. Dried blood and bone meal are disked into the soil at the rate of 2 pounds and 1 pound, respectively, to 48 square feet of surface each time the ground is prepared for seed beds. Commercial fertilizers have not been used in the transplant fields because there cropping has been less intense.

EXPERIMENTS WITH COMMERCIAL FERTILIZERS

Early experiments at Savenac nursery resulted in increased development of pine planting stock grown on soil fertilized with nitrogenous materials. However, the seedlings showed some signs of increased susceptibility to disease in the nursery, and they did not survive field planting as well as similar unfertilized seedlings.

Later intensive experiments with Engelmann spruce showed that its naturally slow growth in the nursery could be safely stimulated by fertilization, and that the better developed, more easily handled planting stock that was produced survived field planting better than similar unfertilized trees. By using moderate[2] applications of dried blood and bone meal or heavy[3] applications of sheep manure, at least a year was saved on the 4-year or 5-year period formerly necessary for the production of suitable Engelmann spruce planting material. A few tests indicated that sodium nitrate in solution may be advantageously used as a stimulator on soils during the growth of crops. Different strengths of solution of this salt applied to some beds of slow-growing 2–0 Engelmann spruce improved the color and growth of puny yellowish seedlings. The strongest solution, 2 pounds sodium nitrate dissolved in 3 gallons of water applied to 48 square feet, killed the weaker plants and injured otherwise healthy green plants. One-pound and one-half pound solutions caused marked improvement in color and growth without injury to any of the seedlings. Both strengths did equally well. Unless the seedlings are sprinkled immediately after this treatment to wash the sodium nitrate from the tops, burning will result. The treatment is also made more effective by washing the chemical into the soil.

More complete fertilization was tried in recent experiments[4] for the purpose of studying means of maintaining soil fertility. Out of 21 trials of various mixtures of three common fertilizers, the best developed 2-year-old western yellow pines were found in a small group of plots fertilized with 160 to 480 pounds of sodium nitrate, 80 to 240 pounds of acid phosphate, and none or less than 30 pounds of muriate of potash per acre. Nearly all fertilizer treatments that were tried increased the top-heaviness of the plants, but improved their development in other respects. The next step in these experiments was to determine the most efficient carriers of these elements. Suggestions as to the most promising materials to be tested were obtained from the early European work of Chancerel (*1*)[5] on the effect of fertilizers on woody plants, and from the results of studies of various agricultural experiment stations in the United States.

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[2] From 1 pound blood and one-half pound bone meal to double these amounts applied to 48 square feet at the time of sowing.

[3] 30 pounds applied to 48 square feet at the time of sowing.

[4] WAHLENBERG, W. G. PROGRESS REPORT ON FERTILIZERS USED AT SAVENAC NURSERY. 1927. Unpublished manuscript.

[5] Italic numbers in parentheses refers to "Literature cited," p. 91.

The 30 common fertilizers listed in Figure 2 were selected for testing. Each of these was tried in two strengths, a light and a heavy dose, so chosen as to be likely to embrace the best treatment. In rating each trial the total stand of 1–0 and the percentage of good 2–0 trees were used as measures of yield, and weight and balance as measures of development. In the absence of a wide range of trials of each fertilizer the most effective amounts must remain undetermined, but of the two doses tried, the one giving the better results is listed in each case on the figure.

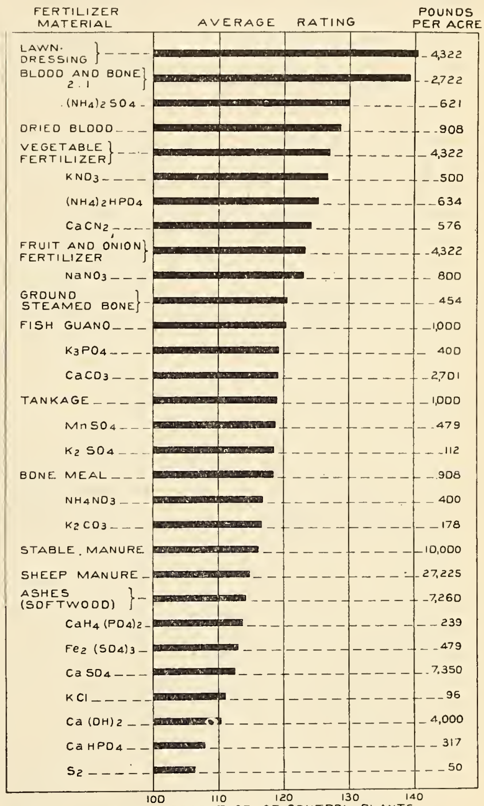

FIGURE 2.—Rating of results of fertilization. Both yield and development of 2–0 western yellow-pine seedlings are considered in ratings which rank the unfertilized controls at 100 per cent

The data may be rearranged in terms of relative results obtainable from each dollar spent for material, freight, and labor by applying current prices to the amount of each class of materials used per acre.

Best results were obtained from a commercial mixture of super-phosphate, bone meal, tankage, and guano containing 4.6 per cent nitrogen and 9.8 per cent phosphoric acid. Treatments with dried blood and ground bone mixed in the ratio of 2 to 1 ranked second. Ammonium sulphate ranked third. Other common fertilizers varied much in the degree to which they benefited yellow pine seedlings, but there was a tendency for carriers of high nitrogen content to yield the best results. Although animal manures did not rate particularly high in all trials when immediate crop responses were considered, their great value in permanent soil management is unquestioned.

STORAGE OF SEED

Seed is not borne upon trees in the same abundance each year. A good seed crop in any region is often followed by one or several very poor or lean crops. Accordingly, during years of plenty, enough seed must be collected to last several years.

The behavior of seed stored over the period between seed crops is important to the nurseryman. Some loss in viability of stored seed is unavoidable, but the amount can be reduced by proper storage.

In some cases, as in the true firs, the loss is so great for a period of only one year, that it is advisable to store the seed in the ground; that is, to sow all the seed when fresh and spread the crop of seedlings over the years by the use of varying age classes for planting stock.

In 1919 a study was started to determine the loss in seed stored in five types of containers. The samples were stored at points widely scattered over the United States, to determine whether seed deterio-

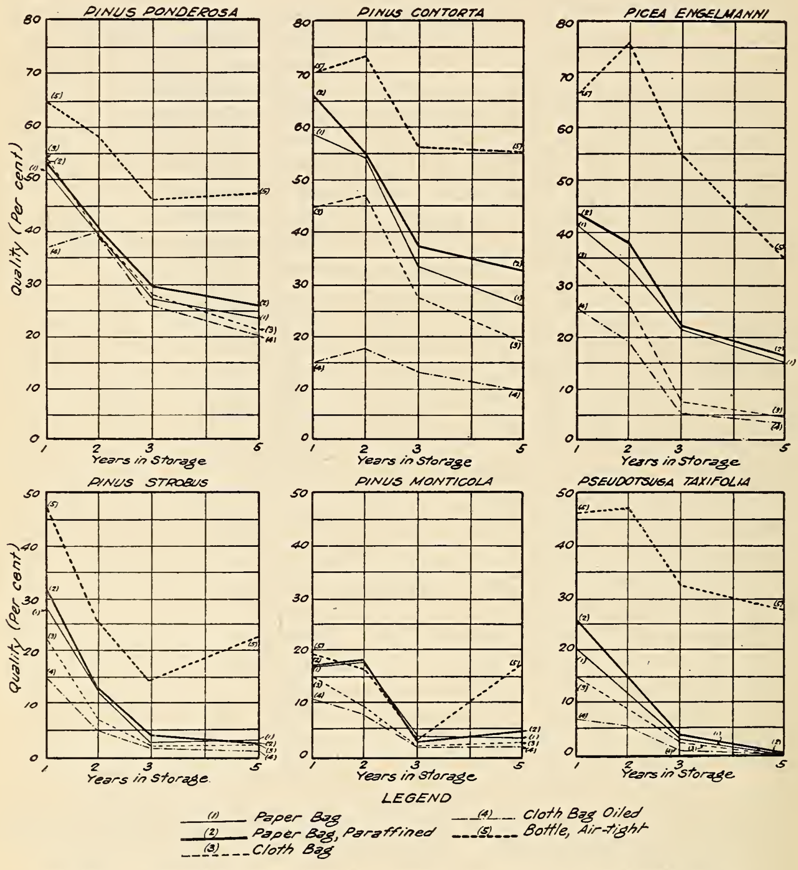

FIGURE 3.—Curves showing quality of seed after 1, 2, 3, and 5 years' storage

rated in storage to a greater extent in one geographical region than in another.

Tillotson (*6*) shows (fig. 3) the quality of seed after 1, 2, and 5 years' storage and summarizes the results of this study as follows:

> Apparently through oversight, no tests of the seed were made before they were put in storage. It is not known, accordingly, to what extent deterioration progressed in the seed during its first year of storage. That there was deterioration in the case of most containers is shown by the very general superiority after one year of the seed stored in air-tight bottles. Because of this lack of an original test, it has, in making analyses of the results, been necessary to use as the basis of comparison, the germination of seed after storage for one year in the air-tight bottles. * * *

In noting the conclusions, the reader should keep in mind that they have reference to coniferous seed only, and that they are based upon the results of one series of tests with only six species of coniferous seed and may not accordingly be applicable to all coniferous seed, or even to the same kinds of seed from other sources. It should also be remembered that the seed used in this experiment was thoroughly air-dried before it was placed in air-tight storage.

(1) Storage of coniferous seed in the air-tight bottle is far superior in every respect to storage in any other container. The average germination for the 5-year period of seed stored in bottles over that stored in the next best container was 22 per cent.

(2) Thoroughly air-dried coniferous seed stored in air-tight bottles is little if at all affected by such differences in temperatures as exist between a location where the temperature follows the natural fluctuations, a location indoors where the temperature never falls below freezing, and a location in an ordinary cellar or basement.

(3) Coniferous seed stored in air-tight bottles is little if at all affected by the geographic location of the storage point.

(4) The quality of coniferous seed, by which is meant its value in terms of both germinative energy and germinative ability, is much superior in the case of seed stored in an air-tight bottle to that stored in any other receptacle. This is manifest even at the end of one year of storage.

(5) Following the air-tight bottle, the various containers, in the order of their merit, fall into the following sequence: Paper bag paraffined, paper bag, cloth bag, and oiled cloth bag. It should be noted that an ordinary paper bag closed at the top is superior to a cloth bag for seed storage. The oiled cloth bag is practically worthless as a container.

(6) The use of any of the containers except the air-tight bottle results in such rapid deterioration after one or two years of storage under the temperature conditions of this experiment as to render the seed, particularly of Engelmann spruce, Douglas fir, and white pine, of very little worth.

(7) Storage at the indoor temperature is superior to that at the fluctuating or low. Storage at the low temperature shows the poorest results. This low temperature has reference not to a low uniform temperature of freezing or less, but to that of an ordinary cellar or basement. The difference in germination percentage is not great under these three conditions, but is sufficient to make indoor storage preferable to the other two conditions.

(8) Some geographic locations are more favorable for seed storage than others. Fort Bayard, Pikes Peak, Pocatello, and Lake Clear Junction—all points of relatively high altitudes, and, with the possible exception of Lake Clear Junction, of low relative humidities—stand out as exceptionally favorable localities. Four middle-western points, Waukegan, Dundee, Lawrence, and Warsaw, and one Atlantic seaboard point, New Haven, stand out as unfavorable localities for seed storage. Such points should apparently be avoided where ordinary methods of storage are followed. No one of the geographic locations shows marked superiority over another when the seeds are stored in air-tight bottles.

(9) In respect to sustained vitality, the seeds employed in this study range themselves in the following sequence, with the strongest first: Western yellow pine, lodgepole pine, western white pine, white pine Engelmann spruce, and Douglas fir.

At Savenac nursery small lots of seed are stored in air-tight glass bottles. Large lots are stored in air-tight metal drums, each capable of holding about 100 pounds of seed. The containers are stored in rooms of low humidity and fairly uniform temperatures yearlong. It is advisable to divide the seed into several lots and store them in separate buildings, so that in case of fire or other damage the whole supply will not be endangered. Of more importance than the cost of the seed is the danger of losing a new crop of seed and being unable to replace it for two or more years.

Chunks of charcoal placed in the seed will absorb moisture in the container and lessen the danger of seed mold. Some commercial seed dealers kill mold forming on the seed with carbon bisulphide fumes.

An open cup containing the liquid is suspended in the space between the mouth of the container and the seed.

PRODUCTION OF STOCK

SCOPE OF THE WORK

Starting in the fall of 1909 on an acre of abandoned clearing in a dense forest, the Savenac nursery made a mushroomlike growth, and by the fall of 1912 it was the largest of the Forest Service nurseries. (Figs. 4 and 5.) Its rapid growth was due to its ideal location for supplying forest-planting stock to the western part of the northern Rocky Mountain district, comprising Montana and northern Idaho. Here the holocaust of 1910 left in its wake more than 2,000,000 acres of burned mountain slopes. Of these burned areas, so many needed planting that the task of reforestation was tremendous. An added impetus was given to the growth of the Savenac nursery when it was

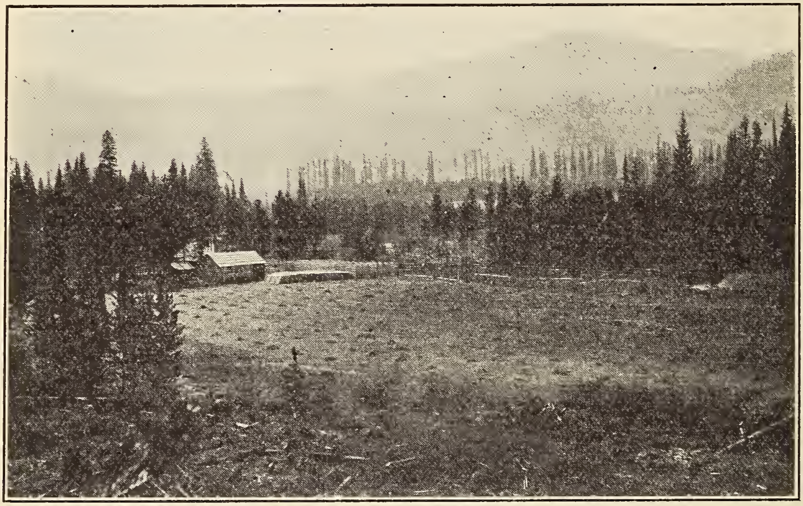

FIGURE 4.—Savenac nursery in 1909

decided to confine forest planting in the Rocky Mountain district to the western white-pine region [6] and to terminate the scattered planting being done in eastern and central Montana. Temporary forest nurseries in Montana were then abandoned and the production of nursery stock concentrated at Savenac nursery.

It was soon realized that scientific research must supplement the meager knowledge at hand for raising forest planting stock under the local conditions. Accordingly, studies were undertaken to solve the numerous nursery problems peculiar to the region and the species to be grown.

[6] The western white-pine region covers the Idaho panhandle, a tip of eastern Washington, and stringers extending into northwestern Montana. In this region climatic conditions are favorable to high survival of planted trees and excellent forest growth. Though white pine is the major type, the western larch, Douglas fir, Engelmann spruce, and western yellow-pine types are interlaced with it. Western white pine, western red cedar, and Engelmann spruce are planted on the north, east, and west aspects, where the soil does not dry out as readily as on the sunny slopes. Western yellow pine, Douglas fir, and western larch, being more drought-hardy species, are planted on the southerly aspects.

Simultaneously it became apparent that the production of stock in large quantities, particularly the machinelike repetition in the motions made in transplanting over 2,000,000 trees each spring, warranted the development of special implements and methods. A thorough study of the transplanting operations was started in 1914 with a view to standardizing operations, creating special implements and devices that would be better suited for the work, reducing costs, supplanting questionable judgment of the laborers with foolproof methods, and speeding up the work so that in the short season favorable to transplanting the output could be increased without the need of a large, unwieldy crew.

Savenac nursery produces annually 3,000,000 trees; and there are in the ground at all times about 10,000,000 trees, ranging in age from newly germinated seedlings to 4-year-old transplants. These trees are used solely for planting on the national forests. Only six

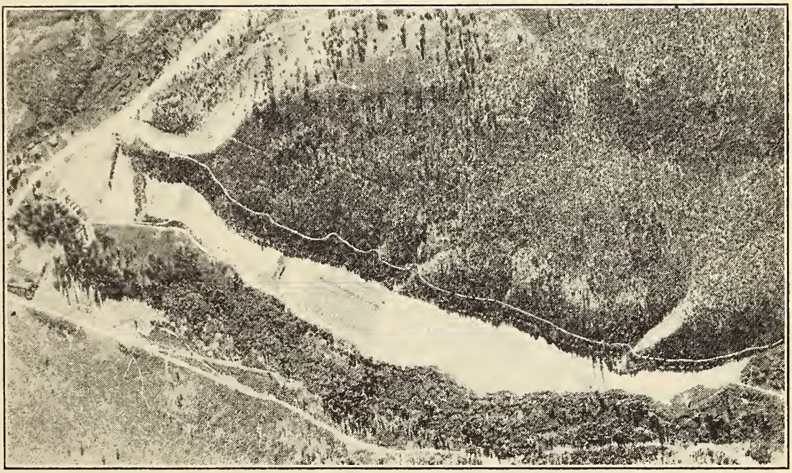

FIGURE 5.—The Savenac nursery from the air, 1928, showing the two small lower benches, used chiefly for seed beds, and the large upper bench, used chiefly for transplant beds. The main ditch shows as a white line on the hillside just beyond the nursery

species are grown which simplifies the nursery practice. These species are western white pine (*Pinus monticola*), western yellow pine (*P. ponderosa*), Engelmann spruce (*Picea engelmanni*), western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga taxifolia*), and western larch (*Larix occidentalis*). All are timber-producing species native to the region. Nursery work and planting—production and consumption—are within the control of one office, a condition which further simplifies the work. The trees are handled in large orders, generally between 20,000 and 50,000 in a lot, permitting the use of heavy-duty implements and of methods that would be impractical where a greater variety of species and smaller orders are handled.

There are 35 acres of cultivated land in the nursery, sufficient for crop rotation and summer fallow. In addition, 4 acres are required for yards and buildings.

The organization devoting its time to reforestation has five distinct lines of work: Planting, planting surveys, planting and nursery research, nursery operation, and seed collection and extraction. All become intimately associated through the coordinating office of planting. So far as the nursery work is concerned, the amounts, species, and age classes of the stock grown are regulated by the main office, and nursery technic is guided by the findings in nursery research. The hiring of men, upkeep of the nursery, and all things pertinent to the execution of the nursery work are made the responsibility of one man, the nurseryman in charge. His assistants are temporary laborers hired only through the active field season. Foremen of the various projects, such as transplanting and shipping, are selected from local labor, generally settlers who can be depended upon to come back from year to year.

CLIMATIC, SOIL, AND OTHER CONDITIONS

For the work in hand Savenac nursery is ideally situated. It is within the transitional zone of the western white pine, western yellow pine and larch-Douglas fir types and thus from a climatic standpoint is suitably located to grow stock for the three principal timber types of a large region. Although the nursery is nested in the heart of the rugged Bitterroot Mountains, shipping facilities and accessibility are exceptionally good as there are two railroads, each with a station within a mile of the nursery, and the Yellowstone Trail Highway passes through the nursery.

The mean elevation is about 3,200 feet above sea level, the range of elevation being 100 feet between the lowest and highest compartments in cultivation. This elevation strikes a fair average between the altitudinal limits (2,200 to 4,500 feet above sea level) of the commercial-timber types of the region supplied from the nursery. The comparatively short growing season, from April 15 to September 15, is general throughout the region, so the seasons at the nursery and on the planting sites coincide; that is, conditions at the nursery are suitable for removing the stock when most of the sites are ready for planting. Snowfall is heavy, which is a beneficial factor in that the heavy mantle of snow protects the nursery beds during cold weather. Frosts may occur in any month of the year. Annual extremes in temperature commonly reach −30° and 95° F., occasionally extending to −40° and 98°. The mean annual temperature based on 20 years' records is 42.1°, with monthly means during the growing season, as follows: April, 42.6°; May, 49.8°; June, 57°; July, 63°; August, 60.9°; September, 53.3°.

The mean annual precipitation for the same 20-year period is 27.41 inches of which only 6.91 inches[7] come during the growing season. July and August, the driest months, have a mean rainfall of 1 and 0.91 inch, respectively. During extremely dry years the combined rainfall for these two months has been less than a quarter of an inch. Artificial watering of the nursery stock is necessary during most of the growing season. Water is amply provided by Savenac Creek, a small mountain stream flowing through the nursery, on which the Government has filed a water right for 432 miner's inches.

[7] Combined monthly mean of April, May, June, July, and August.

The series of benches which comprise the land under cultivation have just sufficient grade to make conditions ideal for furrow irrigation. Most of this land was originally smooth, and only a little leveling was required to put it into good working condition.

The soil is a light sandy loam, averaging about 10 inches in depth. It is especially well suited for seedling culture. It stirs easily even when saturated, and it does not harden when dry, whereas a highly plastic soil can not be worked when wet and dries extremely hard. The wheeling of heavy implements over the ground and frequent walking over the paths between seed beds do not pack the soil to such an extent as to make pulverizing difficult in subsequent plowing and cultivation.

Water from the irrigation furrows quickly permeates the light sandy loam. However, such soil washes easily and must be protected by drop boxes in the irrigation furrows where the gradient is steep.

The subsoil is a deep deposit of coarse gravel which gives excellent drainage to the topsoil but can be kept moist only by frequent watering. Each year some large stones in the subsoil are forced into the topsoil by frost action. As these would interfere with the use of underground root pruners and tree lifters, they are removed from the fields when turned up by the plow.

QUANTITY AND QUALITY OF SEED

Into the seed beds go the plans of nursery production for three, four, and five years in advance. The most important steps in the fulfillment of these plans take place underground, where even the watchful eyes of the nureseryman can not follow developments. The factors that must be considered at the time of sowing are germinative characteristics of the seed, quality of the seed, loss in germination before the cotyledons reach the surface, and deaths immediately following germination. Before sowing, the viability of the seed should be determined as well as the best way of sowing the seed and of taking care of the seed beds afterwards.

It is of prime importance that enough seed be sown to meet the demand upon the nursery for planting stock. It is just as important that the density and distribution be good.

The nurseryman is in constant fear that future nursery production will not reach expectations. In Forest Service nurseries a shortage in stock curtails field planting on the forests, and this means an irrevocable loss because regular amounts of money set up by act of Congress for planting are given in the form of annual allotments. The unused balance at the close of the fiscal year can not be added to the work of the years following. Overproduction is a practical measure to offset unforeseen losses; yet this practice has its drawbacks. Surplus stock held over an extra year naturally increases in cost. Western yellow pine develops so rapidly that any surplus after the trees have attained their proper size for field planting can not be held another year in the nursery without risk of overdevelopment. On the other hand, Engelmann spruce and western red cedar can be held over an extra growing season without this danger. If certain age classes of both seedlings and transplants make suitable planting stock, the choice offers an outlet for over-

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production; for example: Under the growing conditions at Haugan, Mont., 2–0 [8] and 1–2 western white pine are standard age classes for shipment. However, 2–2 stock is superior to both, and 3–0 is as good as 2–0 if the trees are sparse enough in the seed beds to permit normal development a third year. Thus an oversowing originally intended to come out two years hence as 2–0 shipping stock can be distributed as follows:

1,500,000	0–0	Original sowing, allowing 50 per cent overproduction for unforseen losses.
1,400,000	1–0	No abnormal losses to date.
100,000 transplants	1–0	The 50 per cent overproduction reduced to 40 per cent by transplanting 100,000 to go out the third year after sowing.
100,000	1–1	No abnormal losses to date.
1,200,000	2–0	The full 1,400,000 2–0 have completed development in the age class originally intended. The extra 400,000 may be split by transplanting 200,000 from the denser beds for 2–2 stock and keeping 200,000 in sparse beds to grow to 3–0 shipping size.
200,000 transplants	2–0	

From the above it will be seen that 1,000,000 were produced as intended, namely, 2–0 stock. The oversowing of 500,000, none of which were needed in two years, was carried an extra year in the amounts of 300,000 as 1–2 and 3–0 stock and two extra years in the amount of 200,000 as 2–2 stock.

It is noteworthy that greater flexibility is attained when the oversowing is made in blocks of stock originally intended to develop into shipping class without transplanting. When the oversowing is made in stock intended for transplanting as 1–0, it must be decided at the end of the first year what is to be done with the surplus because such stock is grown too densely in the beds to develop into suitable shipping size as 2–0 or 3–0. It must be transplanted and grown into either the 1–2 or 2–2 shipping class, whereas an oversowing made in the lighter seedling densities may be grown into any of the seedling or transplant shipping classes listed above and thereby fill any shortage in production that may occur in any year over a period of three years. A further discussion of plant development in the different age classes and the possibilities of root pruning in place to retard growth for holding over stock in the nursery is given on page 47.

Overproduction should not be brought about by increasing the density in the beds, but by increasing the number of beds. Use the density that has been determined to be the most satisfactory for the various age classes, and compute this density on the basis that no unforeseen losses will occur. The losses will occur in patches instead of being evenly distributed. An increased density is not modified by natural thinning through these losses but actually amounts to raising stock under a density too great for its best development.

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[8] As readers familiar with nursery practice will know, this terminology indicates the number of years spent by the plant in the seed bed and in the transplant bed. For example, 2–0 means that the plant remains in the seed bed 2 years and is not transplanted. Similarly, 1–2 means that the plant remains 1 year in the seed bed before transplanting and 2 years in the transplant bed after transplanting.

There are two general divisions of the stock in the seed beds: Seedling stock, which is to complete its development in the seed beds and requires a longer period of growth in the seed beds; and transplant stock, which will occupy the seed beds until it is of sufficient size for transplanting. Although cheaper to raise, seedling stock is inferior to transplants and for that reason can not compete with the better stock where it is difficult to establish tree growth. On the best planting ground, seedling stock is used. The choice of age classes does not rest entirely with the nurseryman; the condition of the various planting sites determines this.

The planting office undertakes surveys of burned-over areas sufficiently far in advance so that the nurseryman may be informed at the time of sowing what proportion of stock by species will be needed to meet the planting program three or four years later when the stock will be ready for shipment. These surveys show the acreage in need for planting on each burned area by species and the classes of stock that may be expected to do well on the various sites. From these acreage figures, the number of trees by species and age classes that will be needed are computed. These surveys make the basic plan of tree production at the nursery and may be likened to advance orders or to the growing of stock of specified classes in a commercial nursery on contract.

Table 1 shows the standard age classes for Savenac nursery and the percentage of each raised for an annual planting program of 2,000,000 western white pine; 600,000 western yellow pine, 400,000 Engelmann spruce, and 10,000 each of the other species. These percentages are only approximate, as will be seen when a comparison is made with the capacity schedule, Table 2. Oversowings are grown into older than standard age classes in order to fit them into the future plan, and the regular sowings are reduced accordingly. Losses unprotected by oversowings are made up as quickly as possible by increasing sowings in younger shipping classes.

TABLE 1.—*Standard age classes and proportion of each grown at Savenac nursery*

Species	Seedling stock		Transplant stock	
	Age class	Per cent produced	Age class	Per cent produced
Western white pine	2–0	30	1–2	70
Western yellow pine	2–0	40	1–2	60
Engelmann spruce	3–0	80	2–2	20
Douglas fir			2–1	100
Western larch			1–2	100
Western red cedar	4–0	100		

Nursery stock on hand, major forthcoming nursery operations, and future nursery production are conveniently referred to on a capacity schedule such as Table 2.

TABLE 2.—*Capacity schedule at Savenac nursery, spring, 1927*

Species and source of seed	Stock on hand Dec. 1, 1926			Spring changes, 1927	Stock on hand							
					Fall, 1927–spring, 1928		Fall, 1928–spring, 1929		Fall, 1929–spring, 1930		Fall, 1930–spring, 1931	
	Number	Block	Age class		Number	Age class	Number	Age class	Number	Age class	Number	Age class
Pinus monticola:												
Kaniksu, 1920	406,000	14-C-1	1-2, TS [1]	Ship 406,000								
Kaniksu, 1923	1,190,000	21-B-1	1-1, TS		1,190,000	1-2						
Kaniksu, 1920	180,000	14-E	3-0, SS [2]	Ship 180,000								
Kaniksu, 1923	390,000	20-A	2-0, SS	Ship 200,000	190,000	[3] 3-0						
Kaniksu, 1923	1,300,000	20-C	1-0, TS	Transplant 1,300,000	1,300,000	1-1	1,300,000	1-2				
Kaniksu, 1923	1,570,000	20-D	1-0, SS		600,000	2-0						
					970,000	2-0	970,000	2-1	970,000	2-2		
Rose Lake, 1924	295,000	24-A	1-0, TS	Transplant 295,000	295,000	1-1	295,000	1-2				
Rose Lake, 1925	[4] 1,100,000	26-A	0-0, TS		1,100,000	1-0	1,100,000	1-0	1,100,000	1-2		
Rose Lake, 1925	[4] 900,000	26-B	0-0, SS		900,000	1-0	400,000	2-0				
							500,000	2-0	500,000	[3] 2-1	500,000	2-2
Total:												
Ship				786,000	1,980,000		1,995,000		2,070,000			
Transplant				1,595,000								
Pinus ponderosa:												
Bitterroot, 1923	355,000	21-B-1	1-2, TS	Ship 355,000								
Bitterroot, 1923	395,000	21-D-1	1-1, TS		395,000	1-2						
	228,000	21-F	2-0, SS	Ship 228,000								
Bitterroot, 1923	430,000	21-G	1-0, TS	Transplant 430,000	430,000	1-1	430,000	1-2				
Bitterroot, 1923	210,000	21-H	1-0, SS		210,000	2-0						
Bitterroot, 1926			SS	Sow 240,000	240,000	1-0	240,000	2-0				
Bitterroot, 1926			TS	Sow 360,000	360,000	1-0	360,000	1-1	360,000	1-2		
Total:												
Ship				583,000	605,000		670,000		360,000			
Transplant				430,000								

Picea engelmanni:												
Lolo, 1920	115,000	11-A-1	2-1, TS		115,000	2-2						
					300,000	3-0						
Lolo, 1920	380,000	11-C	2-0, SS	Transplant 80,000	80,000	2-1	80,000	2-2				
							360,000	3-0				
Lolo, 1923	460,000	22-A	1-0, SS		460,000	2-0	100,000	2-1	100,000	2-2		
									300,000	3-0		
Lolo, 1926			SS	Sow 400,000	400,000	1-0	400,000	2-0	100,000	2-1	100,000	2-2
Total:												
Ship					415,000		440,000		400,000		100,000	
Transplant				80,000								
Larix occidentalis:												
Kootenai, 1923	6,000	28-A-1	1-2, TS	Ship 6,000								
Kootenai, 1923	11,000	28-B-1	1-1, TS		11,000	1-2						
Kootenai, 1923	8,000	28-C-1	1-0, TS	Transplant 8,000	8,000	1-1	8,000	1-2				
Kootenai, 1926				Sow 10,000	10,000	1-0	10,000	1-1	10,000	1-2		
Total:												
Ship				6,000	11,000		8,000		10,000			
Transplant				8,000								
Pseudotsuga taxifolia:												
Kaniksu, 1921	17,000	16-C-1	2-0, TS	Transplant 17,000	7,000	2-1						
					10,000	2-1	10,000	2-2				
Lolo, 1923	2,000	23-A-1	2-1, TS		2,000	2-2						
Lolo, 1926			TS	Sow 10,000	10,000	1-0	10,000	2-0	10,000	2-1		
Total:												
Ship					9,000		10,000		10,000			
Transplant				17,000								
Thuja plicata:												
Lolo, 1923	9,000	25-A	2-0, SS		9,000	3-0	9,000	4-0				
Lolo, 1926			TS	Sow 5,000	5,000	1-0	5,000	2-0	5,000	3-0	5,000	4-0
Total: Ship							9,000				5,000	
Grand Total:												
Ship				1,375,000	3,018,000		3,132,000		[5] 2,850,000		[6] 325,000	
Transplant				2,130,000								

[1] TS means sown for transplanting and intended to ship as transplant stock.
[2] SS means stock sown at a light density originally intended to be shipped as seedling stock.
[3] Oversowings in white pine. These may be used in the year preceding the one indicated to go out if there is a shortage.
[4] As soon as the seed is sown it becomes part of the plan. Although this seed has not germinated an estimate is necessary to carry out the plan. After actual results of these sowings are known it is too late to correct until sowings are made the following year.
[5] Increase by 2-0 white pine and yellow pine through sowings in fall 1927 and spring 1928.
[6] Increase by sowings in fall 1927-28 and spring 1929.

DETERMINING THE VALUE OF SEED

The number of seed per pound, for all species sown in quantity at Savenac nursery, varies considerably, and the proportion that is viable decreases more or less rapidly with age. General figures, such as are given in Table 3, are an insufficient basis for large nursery operations.

The viability of seed is best determined by germination tests in sand plats. Germination tests in blotters and the Jacobsen apparatus are not as satisfactory for slow seeds because in them mold soon gathers. Cutting tests are all right for approximate work, but unreliable if the seeds have been "baked" in the process of extraction or damaged in other ways that can not be noticed in tests by this method.

In order to have the data available for spring sowing the tests must be made during winter. These can be carried on by the nurseryman if he has a small greenhouse in which to work. Otherwise, the seeds should be sent to one of the numerous State seed-testing laboratories cooperating with the Government in this work.

TABLE 3.—*Number of seeds per pound, average germination and cost per pound of seed of different species of conifers* [1]

Species	Range in number or average number of seed per pound	Average germination of fresh seed	Average cost per pound
		Per cent	*Dollars*
Pinus monticola	24, 400–28, 900	44	2. 95
Pinus albicaulis	2, 874	20	1. 23
Pinus flexilis	5, 610		
Pinus ponderosa	7, 690–9, 200	37	. 55
Pinus contorta	103, 230–137, 160		3. 97
Picea engelmanni	135, 500–233, 000	38	3. 66
Pseudotsuga taxifolia	34, 600–55, 500	41	2. 26
Larix occidentalis	98, 280–152, 180	30	8. 57
Thuja plicata	202, 600–504, 000	73	2. 60
Tsuga mertensiana	207, 910		6. 06
Tsuga heterophylla	274, 875–323, 999		4. 49
Abies lasiocarpa	51, 262		4. 31
Abies grandis	23, 858–44, 270		1. 62

[1] Seed collected in western Montana and northern Idaho, by the Forest Service for use at Savenac nursery from 1911 to 1927, inclusive.

Care should be taken that the seed samples are representative of the lots. The heavier seed and the fine particles of foreign matter mixed with the seed settle to the bottom of the container; the light seeds and needles accumulate at the top. All should be thoroughly mixed before the sample is taken out. From a weighed amount the seed is counted, and the amount of clean seed per pound of gross weight determined. Counted samples of clean seed (generally 200 in each) are then germinated, and from the results of these tests is computed the real value per gross pound of seed.

With the device shown in Figure 6 samples of seed can easily be taken from any part of a large container. The sampler with the lid closed is forced into the seeds to the place where a sample is desired. When the lid is raised by means of a wire attached to it, seeds fill the cone. The lid has a tendency to close when the sampler is withdrawn, thus holding firmly a heaped coneful of seeds.

During the progress of the testing, the mean temperature of the sand should vary between 70° and 80° F. The maximum should not be allowed to go above 100° or the minimum below 60°. It is important that the sand plats be kept constantly moist, but too much water is injurious. The drying of the top of the sand is a signal that water is needed. The sand should not be given more water than it can immediately take up. By watering lightly once each morning, the desired moisture condition can be maintained.

The plats are examined periodically, generally every two days. As the seedlings push through the sand they are pulled out and the number recorded on a germination chart. The configuration of a curve made as germination progresses is the best indication of the status of the test. When this assumes a well-defined horizontal direction, it is nearing completion.

After a number years of testing, there will be found a consistent difference, more or less, between germination tests and germination in the seed beds. This ratio should then be applied as a correction factor in determining the amount of seed to sow per bed.

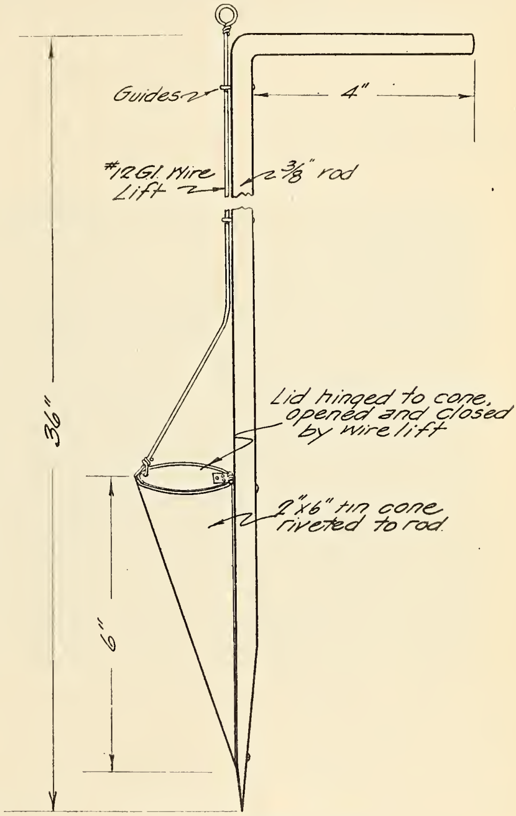

FIGURE 6.—Seed sampler

ALLOWING FOR LOSSES AFTER GERMINATION

The amount of loss incurred from time of sowing to the final stage of packing the trees preparatory to shipment is not fully realized unless an accurate record has been kept. Birds, rodents, disturbance of bed surface, weeding, and unfavorable germinating conditions contribute to this loss up to the time the seedlings are just peeking through the surface. A heavy toll is taken the first year in the seed beds by diseases, insects, sun scorch, frost heaving, weeding, adverse weather conditions, neglect, and mechanical injuries. After the first year losses in the seed beds at Savenac nursery are not so great. Although subject to many of the same injuries, the seedlings have become sturdy plants that can withstand injury without heavy losses. At the time of transplanting, additional losses are sustained through culling and mechanical injuries. First-year transplants bear the loss directly

due to transplanting. Second and third year transplants, like the older age classes of seedling stock do not ordinarily suffer much loss. The most common losses at this time are due to mechanical injuries caused by weeders and cultivators and to rodents, especially ground moles. When the stock is being prepared for shipment, there are further losses due to the culling out of poorly developed plants and plants injured in the process of lifting.

Again the caution is given that these losses should not be made up by sowing a greater amount of seed to the bed but by sowing more beds and thus eliminating any danger of overcrowding.

AMOUNT OF SEED TO SOW

The amount of seed to sow to obtain the desired density (Table 4) may be determined by the formula

$$P=\frac{A\times D}{G\times S\times Z}$$

P=Pounds.
A=Area in square feet.
D=Density desired per square foot.
G=Germination percentage of seed shown by tests, expressed as a decimal fraction.
S=Number of seed per pound (Table 5).
Z=Variable factors, such as, difference between greenhouse test and seed bed germination, or some evenly distributed loss that may be expected which does not endanger the desired density.

Example: In determining the amount of yellow pine seed to sow to a 4 by 12 foot unit bed for a density of 2,400 trees in the resulting stand (50 per square foot), with seed which runs 10,000 to the pound and has a germination test of 50 per cent, the formula becomes:

$$P=\frac{48\times 50}{0.50\times 10{,}000\times 0.96}=\frac{2{,}400}{4{,}800};\ P=\text{one-half pound.}$$

In this example seed-bed germination has been found to be about 0.96 of that secured in the greenhouse tests.

TABLE 4.—*Ideal density of trees in the seed beds*

[A bed contains 48 square feet]

Species	For seedling stock		For transplanting	
	Number	Class	Number	Class
Pinus ponderosa	2,400	2–0	5,000	1–2
Pinus monticola	4,000	2–0	7,000	1–2 2–2
Do	3,000	3–0		
Larix occidentalis	2,000	2–0	5,000	1–2
Picea engelmanni	2,500	3–0	5,000	2–2
Pseudotsuga taxifolia	2,500	2–0	7,000	2–1
Thuja plicata	2,500	4–0	4,000	2–2

SEEDLING CULTURE

SELECTION OF SUITABLE GROUND FOR SEED BEDS

Seedling culture is more exacting in its soil requirements than the culture of transplants. The best ground is selected for the seed beds, where the soil is light, free from rock and other débris, and well drained. Heavy soils are extremely hard to pulverize into a smooth sowing surface. Obviously, lumpy soil causes proportionately large cavities between the lumps. Into these cavities the seeds find their way and become buried too far below the surface to germinate. Sun baking is common in clay soils, resulting in a network of surface cracks that expose the tender cotyledons prematurely. (Fig. 7.)

It is advantageous to have the seed beds in the proximity of the building group where constant attention can be given to them; otherwise they are apt to be overlooked for a day or two, and injury from birds, rodents, disease, or whatnot may occur and may progress until the damage is beyond repair.

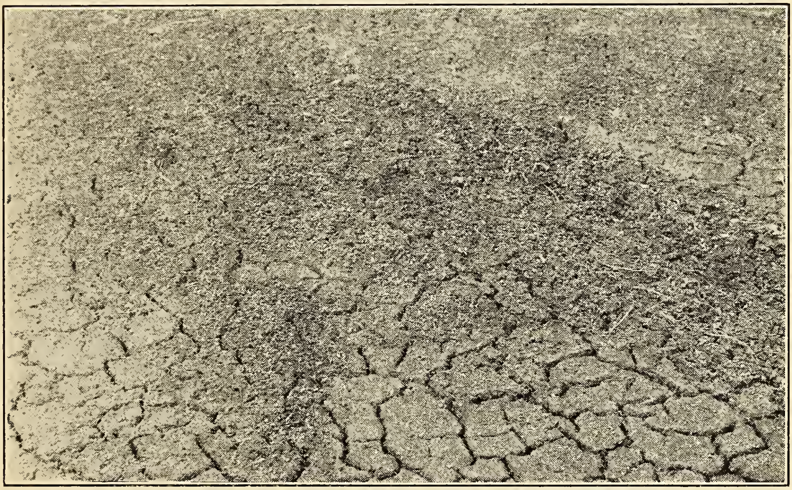

FIGURE 7.—Surface cracking in heavy soil in the seed beds

Germinating seed beds require light but frequent watering. Seed beds in the making often require sprinkling to settle the light dry soil before it can be properly worked. This is especially true with beds prepared for early September sowing at Savenac nursery, where fall rains do not ordinarily occur until the middle of that month. Availability of water at the time the beds are being installed therefore, becomes another consideration.

PREPARATION OF THE GROUND

Plowing and other preparations for making spring seed beds should get under way as soon as the ground can be worked. The earlier the seed is in the ground the better will be the germination and growth the first year. Although warm soil is essential to

germination early sowing before the warm days appear in the spring will result in no harm. The seed coats are softenend by the cold, moist ground, and the seed is thus prepared for prompt germination when conditions are favorable. At Savenac Nursery the ground can ordinarily be plowed the first week in April. For fall sowing, the ground is plowed sufficiently in advance to have the beds ready for sowing the first week in September. Harrowing and cross harrowing follow plowing. Commercial fertilizers are worked into the soil during the harrowing.

ARRANGEMENT AND SIZE OF SEED BEDS

Much labor and expense can be saved by judicious planning of the relation of the compartments of the beds to each other. (Fig. 8.) Stock that is to be left in the seed beds but one year should, as far as possible, be sowed alongside beds that will come out at the same time. Likewise, new beds that are to grow 2-year-old stock may be advantageously installed in ground contiguous to 1–0 spruce and 2–0 cedar that are to be left for two additional growing seasons. Such an arrangement greatly facilitates shipping operations and other activities that can be more cheaply done on large areas with a minimum amount of moving than on small scattered patches. Later when the stock is removed, soiling crops can be grown and plowed in large blocks. The grouping of species that require special care such as shading, heavy watering, and mulching, in like manner reduces the cost of caring for the stock.

The standard width of seed beds is 4 feet, with from 18 inches to 2 feet between for paths. Wider beds can not be conveniently sowed and weeded from the paths. The length of beds may vary. The length of each should, however, be a multiple of 12 feet because the unit bed is 4 by 12 feet, and for this unit all screen frames and shade frames have been patterned. (Fig. 9, B.) If the water pipes are to be installed on the surface, the beds should not be longer than 96 feet in order that the pipes may lie in the cross paths. The standard 50-foot length of hose will then reach to the center of each bed.

MAKING SEED BEDS

The outlines of beds and paths are marked with stakes and heavy twine. Low stakes are recommended so that the string and stakes will not interfere with the operations following. The paths are left free from cross strings so as to keep them open for work.

After the beds have been staked the surface is carefully raked, all large lumps of soil, sticks, and the like being worked to the paths from which such débris can later be collected and wheeled away. A final dressing of the surface by means of narrow boards, 2 feet long, worked over the beds as a trowel is worked over a cement sidewalk, pulverizes the soil and fills in depressions.

Better drainage results when the centers of the beds are raised a few inches higher than the sides. Nothing is gained by scooping out the paths below the margin of the seed beds. Walking around the beds during their installation sufficiently depresses the paths to define their limits and aid drainage.

				All start germination same season and require screen protection				
						All mulched first year and shaded		
		Spring sowing		Fall sowing			Spring sowing	
		Remain two years			Remain one year		Remain three years	
One-year-old western white pine beds. To be left another year and shipped as seedling stock.	Soiling crop	New western yellow pine beds. To be left two years and shipped as seedling stock.	New Douglas fir beds. To be transplanted when two years old.	New western white pine beds. To be left two years and shipped as seedling stock.	New western white pine beds. To be transplanted when one year old.	New eastern white pine beds. To be transplanted when one year old.	New Engelmann spruce beds. To be left three years and then shipped as seedling stock.	New western red cedar beds. To be left three years and then shipped as seedling stock.

ROAD BETWEEN COMPARTMENTS

Remain one year				Remain one year		
New western yellow pine beds. To be left one year and then transplanted.	One-year-old Douglas fir beds. To be left another year and then transplanted.	One-year-old yellow pine beds. To be left another year and then shipped.	Soiling crop	Two-year-old Engelmann spruce beds. To be left another year and then shipped.	Three-year old western red cedar beds. To be left another year and then shipped.	Soiling crop

FIGURE 8.—Chart showing advantages of grouping beds that require similar treatment

TIME OF SEEDING

There are two things that determine in which season seed of the different species shall be sown. First, and by all means most important, is the selection of a season that will give prompt and most complete germination. With some seeds there is no choice. *Pinus monticola*, for instance, must be sowed in the fall to get complete

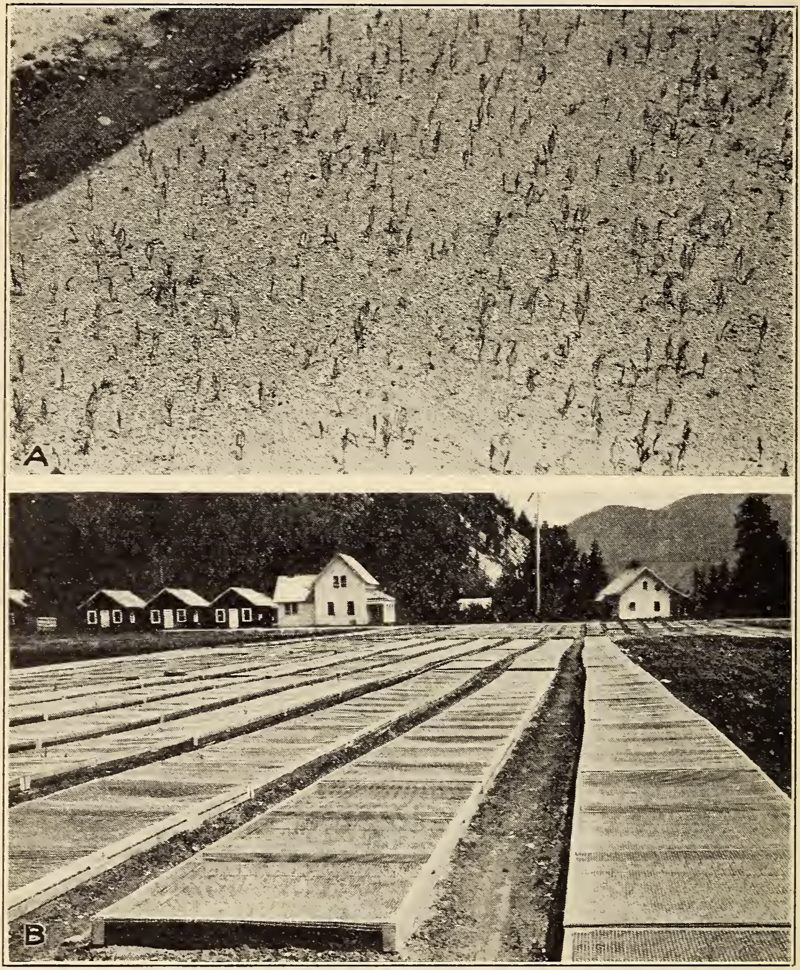

FIGURE 9.—A, Newly germinated western yellow-pine seedlings; B, the low type of screen frame used at Savenac nursery. Cookhouse and bunkhouses in the background on the left, ranger station on the right

germination in one growing season. *Picea engelmanni*, on the contrary, germinates so promptly that there is danger of prewinter germination and consequent freezing when sowed in the fall. Some seeds do equally well from either spring or fall sowing. With these the nurseryman can choose the season that fits in best with his other work; and this is the second point to consider. If he has that choice,

the seeding work may be more evenly distributed between the two seasons or distributed in such a way as better to balance his whole year's program. As a general rule, fall sowing is better for coniferous seeds that do not germinate promptly and completely when sowed in the spring. Seed that starts germinating within a few weeks after sowing should be sowed in spring. (Tables 5 and 6.)

TABLE 5.—*Season to sow tree seeds for best germination and growth at Savenac nursery*

Species	Season	Remarks
Pinus ponderosa	Early spring	Fall sowing slightly better than spring.
Do	Sept. 15–Oct. 15	
Pinus contorta	Spring	
Pinus monticola	Sept. 1–15	No other time satisfactory.
Pinus flexilis	do	
Pinus albicaulis	do	
Laris occidentalis	Sept. 15–Oct. 15	Seed should be soaked in tepid water 5 days before sowing in the spring.
Do	Early spring	
Picea engelmanni	Spring	
Pseudotsuga taxifolia	Early spring	Optional.
Do	Sept. 15–Oct. 15	
Thuja plicata	Spring	
Abies grandis	do	
Abies lasiocarpa	do	
Tsuga mertensiana	do	
Tsuga heterophylla	do	

TABLE 6.—*Minimum time*[1] *required for satisfactory germination of tree seeds as indicated by greenhouse tests at Savenac nursery*

Species	Days	Species	Day
Thuja plicata	24	Pseudotsuga taxifolia	60
Pinus contorta	21	Pinus ponderosa	60
Picea engelmanni	25	Pinus monticola	200
Tsuga heterophylla	23	Pinus albicaulis	200
Tsuga mertensiana	72	Pinus flexilis	200
Abies lasiocarpa	78	Larix occidentalis	60
Abies grandis	70		

[1] Practically the same time is required for germination from spring sowings in the field with the species listed above except the white pines. Both spring and fall sown white pine require more than 200 days in the field for satisfactory germination inasmuch as there are not 200 consecutive days of suitable weather in the short growing season of this region. The period is broken by a dormant spell of from 6 to 7 months during the winter.

Notwithstanding better germination from fall sowing, spring sowing is advised with all species grown at Savenac nursery except the white pines. The nurseryman assumes a definite risk with the fall-sown seed. Frost heaving in the late fall and early spring may do considerable damage to the seed. The mantle of snow occasionally melts, leaving the nursery bare in midwinter, and the unprotected ground freezes hard. A spell of warm weather following, or a chinook with lots of rain (common in January in this region) will mire the top few inches of soil. Drainage is difficult because the ground underneath is frozen. The seed embedded in this mire rots. Furthermore, fall-sown seed beds are subject to rodent pilfering throughout the winter, and little can be done to prevent it. It is difficult to guard the beds against such loss because the protective screen frames can not withstand the weight of a foot or more of snow.

The five needle pines have a strong tendency not to germinate all viable seed the first season after spring sowing. At Savenac nursery this delayed or second-year germination is often as high as 50 per cent with *Pinus monticola*, and has been anywhere from 4 to 91 per cent of the total number germinating from spring sowing. There are several theories regarding the cause of this habit. Chief among them are, (1) the presence of an impermeable seed coat, and (2) the need of an afterripening process in the embryo.

For several reasons it is very desirable to eliminate this hold-over germination. The most obvious objection to it is that a very irregular stand of seedlings is produced. The seedlings are uneven in age, uneven in size, and uneven in their resistance to injury. Seedlings originating late in the season are tender and are scorched by the hot sun of July and August. They die more easily from slight drying of the surface soil than do their companions which are a month or two older. This necessitates the heavy expense of shading the seed beds with lath frames. Then often 20 or 25 per cent of these weak, not yet lignified individuals, are lost over winter from frost heaving and winterkilling. To avoid this trouble mulching the beds with straw is necessary.

In an endeavor to obviate these difficulties many methods have been tried to hastes germination of the western white pine seed, among which may be mentioned: Stratification, sowing fresh seed, soaking in hot or cold water or in acids of different concentrations, dry and moist freezing, sowing in hotbeds, sowing of pregerminated seed, and mechanical methods of cracking, piercing, abrading, or removing the seed coat. Most of these, however, are dangerously artificial methods which, experience has shown, tend to lower germinative capacity and do not uniformly accelerate germination.[9]

Because the results of these trials of spring sowing were all quite unsatisfactory, the possibility of fall sowing was considered. Early experiments carried on at Savenac nursery and the Priest River branch of the Northern Rocky Mountain Experiment Station showed the superiority of fall sowing over spring sowing.

It seemed as if the problem was solved, but it soon appeared that the correct time for doing the sowing was also important. In the fall of 1917 sowings were made on September 7, 17, 27, October 6, 20, and November 3, with two lots of seed. The September sowings showed no startling differences in results, but the October sown beds were inferior in promptness of germination and total number of trees appearing the first season.

During the fall of 1918, seeds were sown on various dates with seed from two sources. The first three weeks in September appear to have been the proper time to sow that year. No seedlings were lost from premature germination; or, in other words, no seeds germinated during the fall of sowing only to succumb during the winter.

Figure 10 indicates that the best time for fall sowing of western white pine seed at Savenac nursery is during the first two weeks in September. According to the graph, the last few days of August may be as good, but August sowings are subject to premature germi-

[9] A full discussion of this subject is given in the following: ROGERS, E. C. DELAYED GERMINATION AMONG THE 5-NEEDLE PINES. 1917. [Unpublished master's thesis. Cornell University.]

nation; that is, germination during the fall of sowing; and seedlings germinating prematurely do not survive the winter.

BROADCAST SEEDING

At Savenac nursery the seed are broadcast in the seed beds. The main advantages of broadcasting over drill seeding are the smaller initial cost of sowing; the comparatively small amount of ground space used for broadcast beds, which results in lower cost of soil preparation, weeding, watering, mulching, and other care; and the better control of the work.

The mechanical advantages of drill rows in preventing overcrowding and in facilitating thinning has in large measure been offset at Savenac nursery by the results of broadcasting the different seeds. Though 1-year-old and 2-year-old seedlings can be readily root pruned while in place in drill rows with a drawknife bent U-shaped, implements have now been perfected that will prune seedlings in broadcasted beds 4 feet wide more cheaply. The cost of transplanting has been so much reduced that when it is necessary to put the trees in rows for greater root development and cultivation, this can be done better and more cheaply by transplanting than by drill sowing.

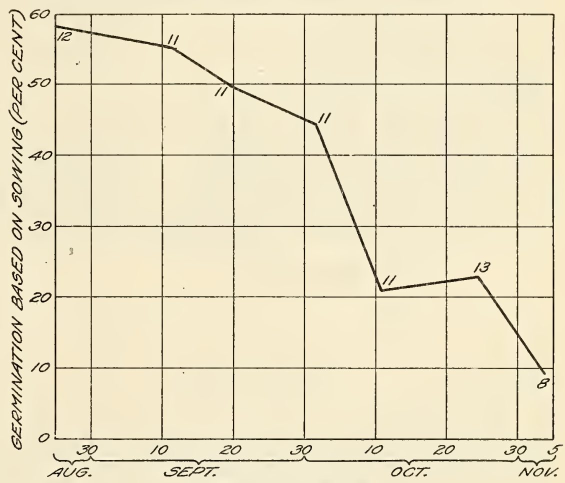

FIGURE 10.—Germination of western white-pine seed at Savenac nursery as influenced by time of sowing in the fall. Based on the results of sowing 77,000 seeds during the years 1916 to 1920, inclusive. Figures in the graph represent thousands of seeds sown

Broadcasting should be done by an experienced and competent man. The seed should be measured in small quantities for sowing. The smaller the unit sowed with each measuring the better will be the distribution. Twelve linear feet of bed (one bed unit 4 by 12 feet) is all that should be sowed from one weighing of seed.

The seed-measuring can shown in Figure 11 is a time-saving device for measuring the amount of seed for each 4 by 12 foot bed when each of a large number of beds is to be sown with the same quantity of seed. An adjustable metal sleeve slips over the can. When the sleeve is fully extended the capacity of the can is approximately doubled. The desired quantity of seed is weighed out and the sleeve of the measuring can adjusted to hold that quantity. The adjusting screw is then set to hold the sleeve at the correct height and thereafter the amount of seed for each bed is scooped from the seed supply and accurately measured by the can. Three cans of different sizes

are used at Savenac. The smallest holds approximately 4 ounces of seed [10] when collapsed and 8 ounces when fully extended. This measure is used for Engelmann spruce and other small-seeded species The intermediate size holds from 8 ounces [11] to 1 pound and is used for western white pine and other species sown in that range of amounts per 4 by 12 foot unit bed. The largest can holds from 1 to 2 pounds [12] and is used to measure the comparatively large western yellow pine seed.

The sower carries the seeds in a pail and scatters them with his free hand. He walks along the path sowing in short arcs from the margin to the center of the bed. If it is difficult to distinguish the seed from the soil so that the uniformity of the sowing can not be judged by the sower a contrast may be brought out by mixing the seed with red lead. Incidentally the bitter taste of the red lead makes the seed less palatable to birds and in that way reduces pilfering in new beds.

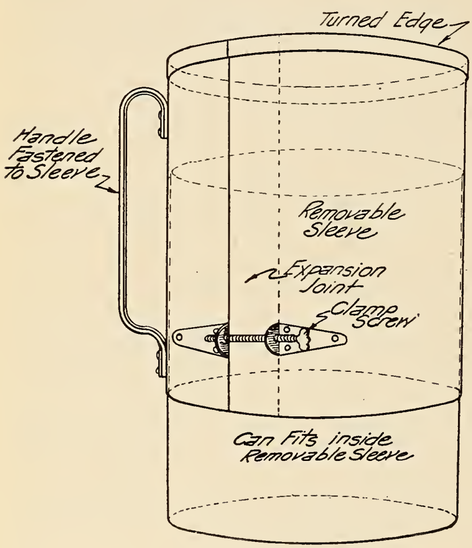

FIGURE 11.—Seed-measuring can

FIRMING THE SEED BEDS

The sowing of the seed has permanently marked the outline of the beds so the stakes and strings are no longer needed. They should be removed to clear the way for rolling and covering the seed. The beds are then rolled to firm the surface and impress the seed in the soil so as to permit a more uniform covering in the operation that follows. The roller used at Savenac nursery (fig. 12, A) is water-weighted cylinder made of galvanized iron. It weighs about 75 pounds empty and 400 pounds when full. Ordinarily it is operated at a weight of about 125 pounds, but the weight is made to vary for different soil conditions. Light dry soil will be pushed before the roller instead of rolled under if the cylinder is too heavy. An irregular surface and lumpy soil should be rolled under a heavier weight. The cylinder is 2 feet in diameter and 5 feet wide—a foot wider than the beds. The extra width simplifies the firming operation on beds raised above the paths in that it is then not necessary to follow the

[10] The weights given here are approximate for western white pine and western yellow pine seeds. Smaller seeds such as Engelmann spruce and western larch are usually lighter by volume, because of impurities that it is difficult to remove from the seed. The persistent wings on western red cedar cause that seed to be very much lighter by volume. Consequently the set of cans described above measures smaller amounts by weight in the smaller seeded species. For example, the small can, when collapsed, will contain only about 1 ounce of western cedar and 2 ounces of Engelmann spruce or western larch seed.

[11] See footnote 10.

[12] See footnote 10.

edges of the beds. However, for beds that are not raised above the paths a 4-foot roller is recommended because if it is wider, the ends will be elevated by high points in the more irregular surface of the paths and the roller will be raised above the beds.

Beds raised slightly in the center to improve drainage must be rolled twice (once on each side) with a short cylindrical roller to firm

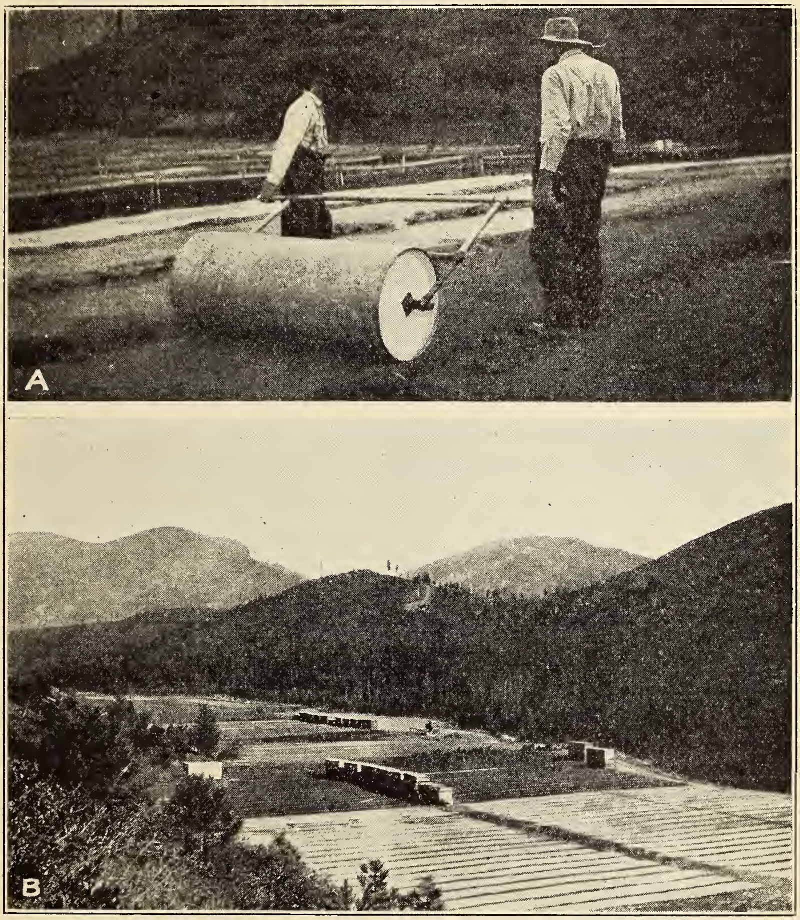

FIGURE 12.—A, Rolling surface of seed beds with water-weighted roller; B, seed-bed compartments

both sides of the sloping surface. The same work can be done in one operation with a roller shaped to conform to the surface of crowned beds. Such a roller can quite easily be made from wood, but a substantial metal water-weighted roller of this shape would be expensive.

If the surface of the roller is wiped occasionally with an oily cloth it will not pick up wet soil and resinous seeds.

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COVERING THE SEED

A proper and uniform depth of cover is essential to the early and uniform establishment of the highest possible number of seedlings from the good seed sown. The seed contains sufficient stored food to bring the plant from a certain depth to the surface, after which it can manufacture its own food. If the seeds are covered too deeply the plants will starve before the surface is reached.

The following depths of cover have been found to give the best results at Savenac nursey:

Western white pine, ⅜ inch for spring sowing.
Western white pine, ⅝ inch for fall sowing.
Western yellow pine, ⅜ inch for spring sowing.
Western larch, ¼ inch for spring sowing.
Englemann spruce, ¼ inch for spring sowing.
Western cedar, ¼ inch for spring sowing.
Douglas fir, ⅜ inch for spring sowing.

A ⅝-inch cover is used for white pine if there is danger of frost heaving in the fall-sowed beds. This slightly greater depth in part

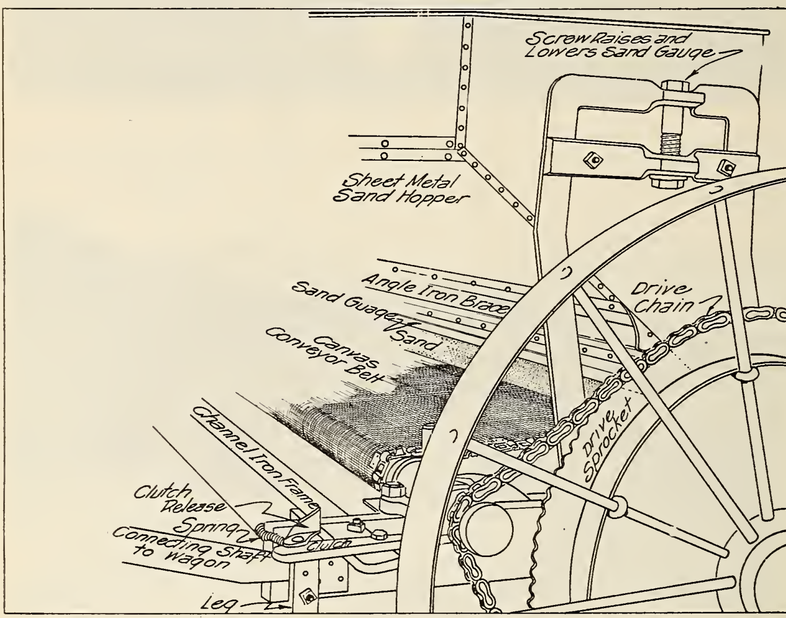

FIGURE 13.—Details of Savenac nursery sand spreader

compensates for loss in cover when frost pushes up the seed during the winter.

Fine river sand makes an excellent cover for the seed beds. It spreads easily. It does not cake, and the young plants penetrate singly without removing large clumps from the surface and exposing other seedlings too tender to appear above the surface. Before being moved to the nursery the sand is screened through ¼-inch mesh screen placed at an angle of 60°.

A machine has been devised at Savenac nursery which accurately gages and applies the sand cover. (Figs. 13 and 14.) Ordinarily

this is drawn over the beds by two men, but where there is sufficient turning room at the ends of the rows of beds for team and wagon a saving in labor is effected by attaching the sand spreader to a wagon or truck which carries the supply of sand.

This method of operating the sand spreader is as follows: The machine is attached to the rear of the sand wagon, and the box of the wagon and the hopper of the sand spreader are connected by a metal chute. The team is wide hitched, so that the horses walk in the paths, one on each side of a row of beds. One man mounts the load to scoop the sand into the hopper. As the spreader is drawn along, chains from sprockets on the two wheels of the spreader revolve a canvas belt in a fashion similar to the endless slat bottom of a manure spreader. This belt conveys the sand from the hopper

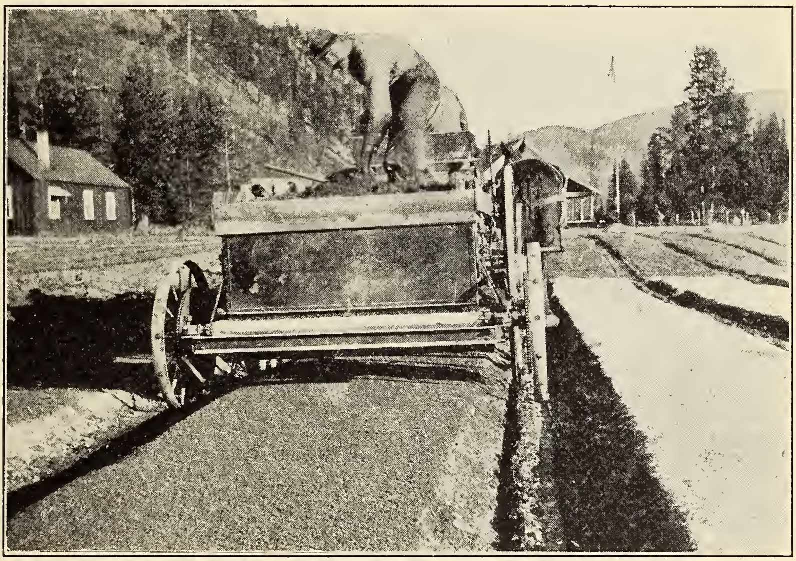

FIGURE 14.—Savenac nursery sand spreader attached to sand wagon

forward and deposits the sand on the ground as the belt turns over on the front roller. The sand is gauged into a smooth layer of any desired depth on the canvas by a lip attached to the outlet of the hopper. The sand must pass under this lip. Since the belt is driven by the traction wheels the speed of the implement does not affect the depth of cover. The canvas belt stops when the spreader is at a standstill and increases in speed as the speed of the spreader is increased. The drive sprockets are half the circumference of the traction wheels, consequently the sand as it is gaged on the conveyor belt is twice the depth at which it is deposited on the ground.

The machine has a clutch so that the belt can be thrown out of gear when the implement passes over idle ground and roadways.

In covering the seed by hand, men carry the supply of sand in wheelbarrows and scatter it with shovels, throwing it on with long, sweeping motions. Others follow with short boards or trowels and smooth the sand cover as uniformly as possible. (Fig. 15.) At best

this hand method does not make a uniform cover; some seeds are buried too deep, while others are left so near the surface that the first rain washes them out.

Comparative costs of the machine method and hand method of covering the seed beds may be briefly summed up as follows: Six men including the teamster hauling sand comprise the crew used in covering seed beds by the hand method. When the sand spreader is attached to the wagon one man in addition to the teamster can cover as many beds as the hand crew; and when the spreader is drawn by hand, as is most practical on short rows of beds, the teamster hauls the sand to a convenient place for loading, and two men operate the spreader. Thus, there is a saving in labor of three

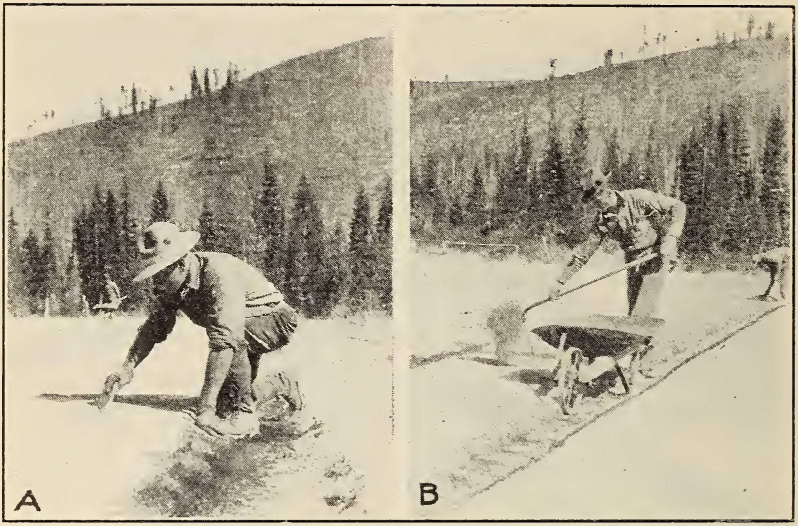

FIGURE 15.—A, Applying the sand and evening the surface; B, hand method of covering seed beds

men when the sand spreader is drawn by hand and of four men when it is attached to the sand wagon.

The original machine cost $300. Later a duplicate was made for $150.

Rolling the beds after covering is advisable, especially when the cover is applied by hand; for the roller will both firm the cover and tend to equalize uneven distribution. (Fig. 12 A.)

CARE OF SEEDLINGS

The Germination Period

WATERING

Seed beds are given special care while germination is in progress. Watering is frequent but of short duration, and the water is lightly applied, to keep constantly and uniformly moist the zone in which germination takes place. A spray is used. Heavy drops would indent the surface and wash the soil cover. Watering through burlap stretched over the surface of the beds is practiced by some nurserymen to break the force of the water applied from a hose.

SHADING

Western red cedar, Engelmann spruce, Douglas fir, and western larch require shade during the germinating period to protect the tender cotyledons from sun scorch on especially warm days in spring. Shade frames (figs. 9, B, and 16) serve a double purpose at this time in that they also afford sufficient protection to the newly germinated seedlings against the light frosts which commonly occur during this period.

SCREEN-FRAME PROTECTION

The seed beds are protected against pilfering by rodents and birds from the time the seed is sown until germination is complete. Birds are by far the more troublesome at Savenac nursery. Large flocks swoop down upon the unprotected beds and eat immense quan-

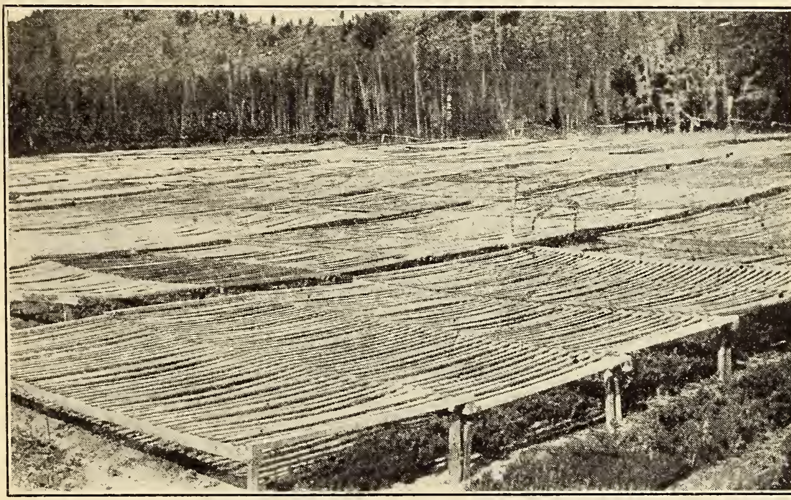

FIGURE 16.—Low shade

tities of seed. The purple finch is the most common ravager. The few cats harbored at the nursery to keep down mice in the buildings are not effective in chasing away the large flocks of birds, and rarely do they cope with chipmunks and moles. The ordinary type of scarecrows has been tried and found utterly useless.

Screen frames offer a means of protecting the beds from such pilfering. The frames used at Savenac nursery (figs. 15 and 17) are boxlike affairs 4 feet wide, 12 feet long, and 4½ inches high, covered on the top with ½-inch galvanized-wire screen. They cost about $4 each for labor and materials. The sides are made of two 2-inch strips with a half-inch aperature left between for ventilation over the beds. A preservative treatment of creosote is given to the lower pieces that come in contact with the soil, to prolong the life of the frame. The life of the treated frames is about 10 years, after which the wire is salvaged for new frames.

The total height, 4½ inches, gives ample room for the growth of seedlings up to the time that germination is practically complete

and the seed coats have been shed from the seedling tops. After that the screen frames, being no longer needed, are removed. This type is low in comparison with the Pettis frame used in some nurseries, but, since these protectors are removed as soon as the seeds have germinated, that feature in no way decreases its effectiveness The Pettis frame has screened sides 12 inches high with a removable top. The high sides weaken the structure, and warping soon causes much annoyance in fitting the top and sides together. Furthermore, the high frames are more expensive to construct, are shorter lived, and require at least twice as much storage space when not in use. At Savenac nursery no advantages in the high frames have been found excepting for beds of experimental stock that are to be given special protection until the seedlings are removed, in which case high frames are necessary to allow room for several years of height

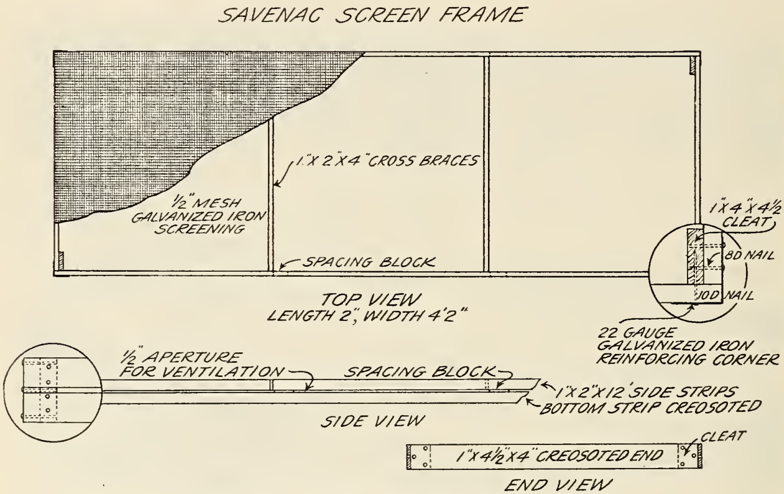

FIGURE 17.—Details of Savenac screen frame

growth. For such beds the wire screening is extended below the bottom rail, and when the frames are set in place this overlapping screening is embedded 4 to 6 inches below the soil surface to exclude rodents.

One should not lose sight of the large investment involved in screen frames for a great number of beds. The annual depreciation in frames is from 30 to 40 cents, the exact amount depending upon the salvage value of the wire mesh after 10 years of use; and the cost of handling these frames brings the total 5 cents higher for each bed annually. It is noteworthy that this cost may become more than hiring boys to keep the birds and rodents away during the germination period will cost.

PERIOD REQUIRED FOR SEED TO GERMINATE

Germination is rapid for western red cedar and Engelmann spruce. (Table 6.) The first seedlings will appear from a week to 10 days after sowing, and in the fourth week germination is practically

complete. Western larch is equally prompt when soaked before sowing. The germination of western yellow pine and Douglas fir starts in the third week after sowing, accelerates during the fourth and fifth weeks, and then gradually slackens until it is practically complete two months after sowing. Fall-sown western white pine appears after a month of spring, and germination is complete a few weeks later.

STIMULATORS

That certain chemicals in the soil stimulate the germination of some seeds was indicated in the course of two chemical treatments used for other purposes at Savenac nursery. Zinc sulphate, applied on seed beds to kill weed growth, has been found to hasten the germination and stimulate the growth of western yellow pine seedlings. Sulphuric acid, used as a fungicide to control damping-off, has likewise been found to hasten western yellow pine and western white pine germination and to stimulate seedling growth.

The Weed Problem in Seed Beds

Weed seeds are brought to the nursery by wind and water, and with straw mulch and manure. It is impossible to shut out this migration of seed completely, but the quantity may be greatly reduced by plowing under weeds grown on unused portions of the nursery, filtering the water used for irrigation, choosing carefully the material used for mulching, and by composting the manure.

The three most important troublesome weeds at the nursery are field or sheep sorrel (*Rumex acetosella*), common timithy (*Phleum partense*), and white clover (*Trifolium repens*). These are all very prolific. It is impossible to remove the sorrel by hand and get all of the root system except in the case of very young plants. The roots send runners far and wide. When roots 2 or 3 feet long are extracted they often do considerable damage by uprooting tree seedlings or disturbing the roots of many trees. Then broken sorrel roots remain in the ground to sprout new plants. Clover and timothy are important, because of their abundance and their bushy root systems.

Miscellaneous weeds as follows, have been identified: *Achillea lanulosa* Nutt., yarrow; *Brassica campestris* L., turnip or navew; *Chamaenerion angustifolium* (L) Scop., fireweed; *Chenopodium album* L. lamb's-quarters; pigweed; *Gnaphalium palustre* Nutt., low cudweed; *Veronica peregrina* L., purslane, neckweed; *Lappula occidentalis* (S. Wats.), Grene stickweed; *Gayophytum ramosiasium* Torr. and Grey, branching gayophytum or kitchen weed; *Tissa rubra* (L) Britton, sand spurry; *Phacelia heterophylla* Pursh, variant or diverse-leaved phacelia; *Sagina saginoides* (L) Britt., Arctic pearlwort.

The weed problem in seed beds at Savenac nursery has been annoying, to say the least. Because the seeds are broadcast as a general practice, weeding must be done by hand. Cultivators are out of question, and even the small hand-weeding tools are useless under such conditions. The weeds must be pulled out with the fingers. So much for the actual weeding. But there have been

greater difficulties. The seed is sown densely in the beds; therefore, when a weed is removed it carries with it a number of seedlings and disturbs the soil around more. Early weeding, when the weeds are small, in no way reduces this damage; for the seedlings are also smaller or have not as yet appeared above the surface. They are not deeply enough rooted to withstand a slight disturbance. It is a question whether more trees are lost by weeding or by weeds.

CHEMICAL WEED ERADICATION

A solution for this difficulty has been revealed through an intensive study with herbicides (*8*). It has been found that zinc sulphate moderately diluted in water is effective in controlling all weed growth from seed without injuring *Pinus monticola*, *Pinus ponderosa*, and *Picea engelmanni*. *Thuja plicata* is damaged by the treatment.

The treatment is as follows: Commercial zinc sulphate is stirred into solution at the rate of 4½ ounces to 1 gallon of water, and applied to the beds at the rate of 3 gallons to 48 square feet. The application is made immediately after the beds have been sowed and covered, in both spring and fall sowing practice.

Results from year to year have varied a little, but for two seasons following each application the number of weeds present in the seed beds has been reduced 80 to 100 per cent. The treatment is a preventive rather than a cure because its effectiveness lies in destroying the weed sprouts as soon as they burst through the seed coat. It does not kill advance growth of weeds nor root sprouts. Zinc sulphate appears to be fatal to clover seed, and effectively eradicates sorrel and timothy. Most of the native weed seeds fall an easy prey. In general the grasses have been observed to be least affected, and wheat seeds appear to be immune or nearly so.

The treatment is as effective the second year after its application as the first or until the soil is disturbed by removing the trees or plowing. Once the soil has thus been disturbed, weeds will reappear. It is fortunate that the toxicity of the zinc sulphate is lost when the ground is plowed; otherwise the treatment would complicate matters. Soiling crops, for instance, would succumb as readily as weeds.

Chemical methods have reduced the annual cost of weeding the seed beds at Savenac nursery from 56 cents to 18 cents per bed of 48 square feet. However, the most important usefulness of this chemical treatment lies in a reduction of loss of stock in the process of weeding.

The treatment should be used with caution. The soil may become toxic to plants after continued treatments. Direct toxic action by zinc ions is distinctly to be feared from repeated applications. Although less probable, acidity might be increased to the point of being injurious to cover crops planted in rotation or even to young conifers. If there is a tendency to greater acidity, equilibrium may be maintained by weakening the solution for a time or omitting it entirely one season. Furthermore, this treatment is not practiced where the weeding is only a small problem; nor in such cases would the hazards of hold-over effects in the nursery, although apparently slight, be justified. In the writer's opinion the chemical treatment

is of most value where it can be used to gain the upper hand areas badly overgrown with weeds. Thereafter, weeds can be easily controlled by hand methods, and that should be the practice.

HAND WEEDING

Implements as a rule can not be used in weeding the seed beds. As previously stated, the small weeds must be pulled out with the fingers. Large perennial weeds such as clover and dandelion are uprooted with a narrow steel blade, forked at the point, if by so doing the sacrifice of young seedlings is not great. Otherwise, the large weeds are cut off at the root collar. The weeds are carried off the field in wire baskets and later used for compost. Weeding should be frequent enough to get the weeds when they are small, so that uprooting the weeds will not greatly disturb the surrounding seedlings.

THE CARE OF PATHS AND EDGES

Paths and edges are weeded with hoes or hand cultivators. The flame of a blow torch has proved effective as a means of killing weeds in such places. There are numerous herbicides that will kill all vegetation in permanent walks and driveways. Some of these are common salt (sodium chloride), creosote, kerosene, sulphuric acid, and white arsenic.

Shading

Engelmann spruce, western red cedar, western larch, and Douglas fir require shade the first year in the seed beds. Engelmann spruce is not exposed to full sunlight in July and August until the third year. Without shade western red cedar suffers at all ages in the nursery on hot bright days.

Western white pine from seed sown in the spring requires shade the first summer to protect the succulent seedlings that have germinated late in the season. With the more common practice of fall sowing, germination is prompt the following spring, so the seedlings have become woody by midsummer and are therefore able to withstand the hot sun without shade.

Western yellow pine is not shaded at the Savenac nursery.

Shading is commonly done with latticework. The density of the shade is regulated by the spacing between laths. One-half shade is obtained by spacing the laths their own width apart; one-fourth shade, thrice their width apart, and so on.

There are two common types of shading—high and low. High shading (fig. 18) clears the heads of men and horses working on the seed-bed area underneath. Wire-woven lath is spread out on a frame structure during hot weather and rolled up and removed in the fall. The framework, however, in order to be substantial is permanently installed in the seed-bed blocks.

Low shading (fig. 16) is obtained by setting 4 by 12 foot lath frames on four short corner stakes, or placing the lath frames on top of the screen frames. The shade frames are constructed from two pieces of lumber 2 by 2 inches by 12 feet and two pieces 1 by 2 inches by 4 feet nailed together to form a 4 by 12 foot rectangle; and sufficient 4-foot lath are nailed across the frame to give the desired shade. It

costs 90 cents to construct such frames at Savenac nursery, and they last about eight years.

The shade frames must be tilted over when the beds are weeded. It is not necessary, however, to move the frames when the beds are watered. The removal of shade is gradual. About the last week in August, when the hottest days are past and the time approaches to abandon shading in early fall, the frames are removed each evening but again put in place during the hottest part of the afternoons. After about a week of this treatment the frames are permanently removed.

Low shading is preferred at Savenac nursery because the low frames may be set up in any part of the nursery without permanent supports, whereas the practice of high shade must be confined to a limited area in the nursery because of the cost of the permanent high-grade supports. The desired freedom in using seed-bed compartments for any species is lost with high shading.

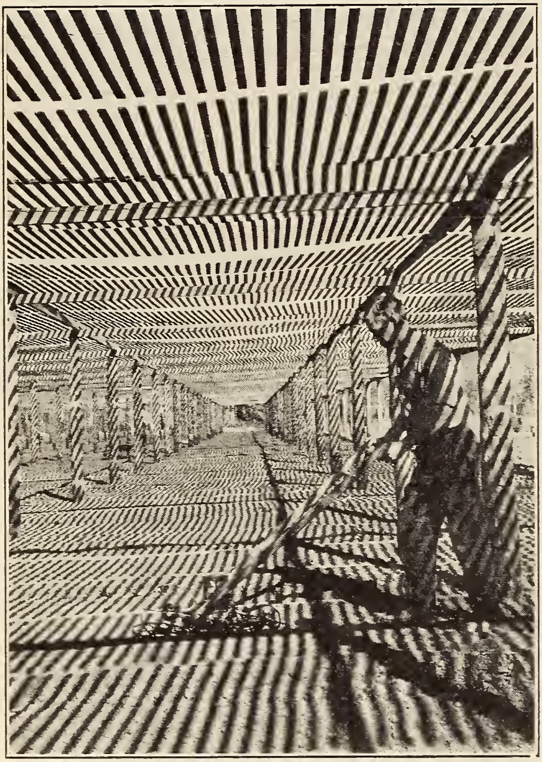

FIGURE 18.—High shade

MULCHING

In a general way, the species that require shade in summer, need mulch over winter. Both treatments offer protection against the extremes in temperature under which the tender trees suffer. At Savenac nursery the species that require shade at any time are mulched the first winter in the seed beds to protect them from frost heaving and winterkilling. Likewise, spring-sown western white pine requires mulch the first winter to protect from freezing the young seedlings that sprout late in summer. Western yellow pine is not mulched.

Deep snow is a splendid protection to the seed beds, but ordinarily low temperatures prevail before and after the snow, so a mulch of straw or leaves must be used. Leaves form the best mulch because they are free from weed seed and form a light cover that is not likely to mat and heat the beds. They are, however, difficult to procure in large quantities in the West. Pine needles are not abundant in the burned-over region around the nursery, and there-

fore can not be economically gathered for mulching. Whole straw, especially rye straw, makes a good mulch. A 50-pound bale of rye straw will mulch fifteen 4 by 12 foot beds with a covering 2 inches deep. (Fig. 19.) Broken straw is unsuitable because the fine chaff it contains will cake and mold. Burlap makes a poor mulch and in addition is very expensive to use for this purpose.

Mulch is generally spread over the beds as soon as heavy frost may be expected in the fall, and it should not be removed until the danger of spring frosts has passed. As spring approaches the mulched beds should be carefully watched so that heating and advanced growth may be immediately noticed and checked by removing the straw. The mulch is raked from the beds and left in piles either for mulching a second time or for compost.

Watering the Seed Beds

Since evergreens do not readily wilt when moisture is insufficient and are difficult to revive when this injury becomes manifest, the

Figure 19.—Seed beds mulched with straw. The stakes are supports for shade frames

utmost care must be taken to see that the seedlings are amply watered. A plant which wilts easily, such as the petunia, will warn the nurseryman that the soil is becoming dry.

Overhead watering can be better controlled and more uniformly distributed than furrow irrigation and flooding. It it therefore the system preferred for watering seed beds. During the germinating period at Savenac nursery the beds are sprinkled for about 10 minutes each day. Later, as the stock develops, watering is less frequent, but about the same total amount of water per week is supplied.

At Sarenac nursery observations and a few experiments show no particular benefits from sprinkling in the early morning or the cool of the evening. It was at one time thought that sprinkling during the hottest part of the day would be injurious to the seedlings because the water collected in the rosette of top needles might intensify the

heat of the sun shining through it, thus causing injury to the terminal bud. A study of this proved the impression to be unfounded. However, water loss through evaporation in morning and afternoon watering is greater than in evening watering, and the effect of the watering is more quickly dissipated.

The water becomes hot if left standing in surface pipes during hot afternoons and should be drawn off before any is applied to the beds to avoid the danger of scalding tender seedlings.

Experiments with numerous types have shown that the ordinary lawn sprinkler of cast iron or zinc known as the C. B. G. type, and twin sprays, are the most satisfactory under the conditions at Savenac. These slide easily along the ground when pulled with the hose, and are flat so they will not topple over. They are simple in construction, cheap, and throw a fine mistlike spray. Devices that spray the water from small perforations are not at all satisfactory at Savenac

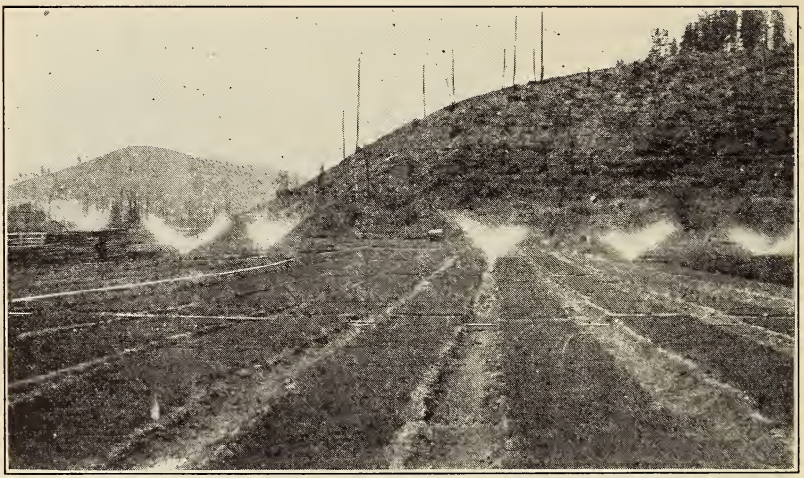

FIGURE 20.—Sprinkling the seed beds

nursery because they soon become clogged with sediment, algae, and other materials carried in the open ditch to the water tank. The ditch has so slight a gradient in its course of more than a mile that drop boxes for aerating the water to eliminate the formation of scum are out of the question. Fine screens placed in the tank to strain the water likewise quickly become coated with scum and must be replaced or cleaned every day to permit passage of the water.

At Savenac nursery from 10 to 15 sprinklers are operated simultaneously. (Fig. 20.) Under 50 pounds pressure, each waters thoroughly a 24-foot circle; accordingly a sprinkler is placed in every fourth path. The first setting is made with the hose extended its full 50-foot length from the pipe line. (Fig. 21.) After sufficient watering, the next setting is made by pulling up the hose half its length, and the third set-up is made at the pipe line. The hose is then laid out on the other side of the pipe line and the operation repeated as above. When all of the area that can be reached with 50-foot hose lengths has been watered, the operations are carried to another pipe line.

Care of Seedlings after First Year

As the stock becomes older it requires less care. Many little refinements necessary in the proper care of first-year seedlings can be dropped the second year with no appreciable injury to the trees. Of the species grown at Savenac nursery, only Engelmann spruce and western red cedar are shaded the second year. No mulching is put on seedlings after the first year. The beds are no longer protected by screen frames. Watering need be less regular. Hand weeding where necessary is simpler because the tree seedlings are better rooted in the ground and not so easily disturbed. The period of constant watchfulness for damping-off, sun scorch, and frost heaving has passed and the stock is sufficiently sturdy to withstand mechanical injuries of various kinds.

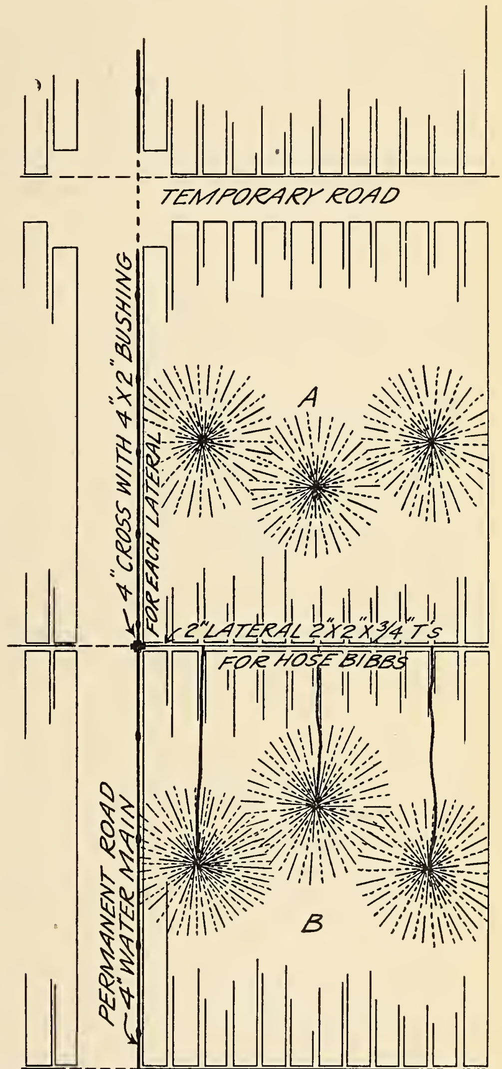

Figure 21.—Method of sprinkling seed beds with lawn sprinklers and surface pipes. After upper half of section A has been watered, the hose are pulled over to water the lower half of section B, using the same bibbs for both set-ups. Note beds are shorter at intersection of driveways to permit turning room at corners for vehicles and implements

CONTROL OF ROOT SYSTEM

In the propagation of ornamental trees and shrubs, first consideration is given to the condition of the tops—size, form, and thriftiness. Forest-nursery stock, on the other hand, should be judged by the condition of the root system and the balance between top and roots. Unlike ornamental stock, these trees are outplanted on the forests where no care is given to them after planting. The trees must be well rooted to survive the shock caused in the change from deep soil and regular watering in the nursery to the hot, dry, exposed slopes in the mountains. During the short growing season of the northern Rocky Mountain region the outplanted trees do not the

first year extend their roots appreciably below the depth of planting. The trees are at a standstill so far as growth is concerned, the successful ones barely holding their own against the severe conditions of the new site. Consequently, the trees must have at the time of planting a root system that will meet the demands of the transpiring tops—what is termed by nurserymen "balance."

Cutting the roots stimulates the development of numerous new laterals, and these fine rootlets branching from the main roots form the bushy system so much desired by nurserymen. This is accomplished by pruning the stock before transplanting or by pruning in place. At the same time root pruning temporarily retards top growth. Thus balanced stock is developed. (See fig. 40.)

Importance of Balance

Leave a tree undisturbed in the nursery and in form it soon becomes no better than wild stock. A yellow pine seedling will, in its first year, send a root 2 feet into the ground. Unless checked by pruning, the roots reach farther out as the tree grows older, and these far-spreading roots can not be taken up with the tree except with painstaking care. Consequently, the network of rootlets comprising the greater portion of the root-absorbing system is left in the ground when the tree is removed. The top, however, continues to grow in equal proportion to the roots, and its size is in no way reduced when the plant is taken up. The tree has become top-heavy. That is why it is difficult to transplant wild stock successfully; why young trees are said to withstand the shock of transplanting better than old trees; and why nurserymen are in business. By pruning the roots when young, the root growth is confined near the stem, and a minimum of digging is required to remove the root system necessary to support the top.

Distribution of Rootlets

The tips of the roots are most active in producing root hairs, the vital members that make the contact with soil particles to absorb moisture. If these tips are cut off or broken off by ordinary methods of digging stock, that part of the tree most important to its survival and growth when transferred to a new location is left in the ground. Pruning causes these fine rootlets to develop near the axis of the root system.

Whenever planted trees are likely to suffer severely from drought, the planting of longer roots in deeper holes is a help. Likewise, if there be a large portion of the total absorbing root surface in the lower part of the planting hole, there is an advantage to the plant. Root length and the distribution of lateral rootlets may have as much influence on drought hardiness as the general bushiness of roots. If the energy used by the trees in producing roots more than 8 inches below the surface—the sections that are inevitably lost in pruning—can be turned into the production of more root branches between the depth of 4 and 8 inches, more drought-hardy planting stock will result. For instance, at Savenac nursery all stock removed for shipment has roots pruned 8 inches below the line of the ground

in which it grew in the nursery. The typical root form of yellow and white pine seedlings is obconical, that is, resembling an inverted cone. The tree has long lateral roots near the surface and successively shorter ones below, consequently, the greater half of the absorbing surface is in the first 4 inches of the root system. But the roots in the zone from 4 to 8 inches below the ground line are more important to the trees because those roots can function in the moist soil whereas the uppermost roots are very apt to be in dry soil the first summer before they commence growth and reach out to the moist soil. The shallow roots dry up and die.

The possibility of so modifying the root form of nursery-grown trees as to produce the greatest number of roots in the zone from 4 to 8 inches below the ground, is being studied in a number of experiments carried on at Savenac nursery. Five soil factors influencing the behavior of roots are recognized; (1) moisture, (2) fertility, (3) physical properties, (4) aeration, and (5) temperature.

In a recent experiment[13] to determine the possibility of modifying the typical root form of yellow pine in seed beds without pruning,

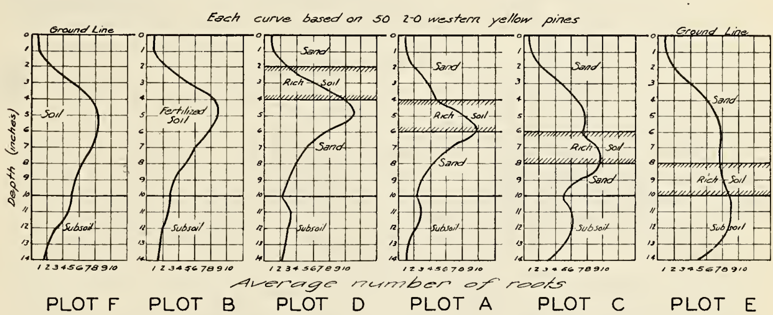

FIGURE 22.—Influence of soil on root frequency

the results clearly indicate that root development can be stimulated locally in any desired part of the root system by means of layers of rich soil. This influence is shown in Figure 22, by the frequency of roots at different depths.

Underground root pruning and transplanting are the principal means of changing the natural form of the root mass. These operations check the growth of tops and stimulate root ramification.

UNDERGROUND ROOT PRUNING

Underground pruning alone is not an adequate substitute for the more expensive operation of transplanting. Devices have been perfected to overcome the mechanical difficulties of underground root pruning, but until a more uniform spacing of plants by the broadcast method of sowing seed can be attained, transplanting will continue to be the most practical means of modifying the root systems.

Underground root pruning is resorted to at Savenac nursery only when there is an overproduction of stock in the nursery that

[13] WAHLENBERG, W. G. MODIFICATION OF WESTERN YELLOW PINE ROOT SYSTEMS IN THE NURSERY. [Unpublished progress report.]

can not be transplanted or shipped, and then only with western white pine, western yellow pine, and western larch. The other species, Engelmann spruce, western red cedar, and Douglas fir have naturally spreading shallow root systems that would be little changed by pruning. Pruning in place retards the growth to such an extent that the stock can be held an extra year without serious over-development. White pine pruned in place when 1 year old is of excellent size for transplanting a year later. The growth of yellow pine has been successfully checked the second year to make suitable 2–2 transplant stock. White pine pruned in place at the age of 2 years develops into good planting stock the third year in the seed beds

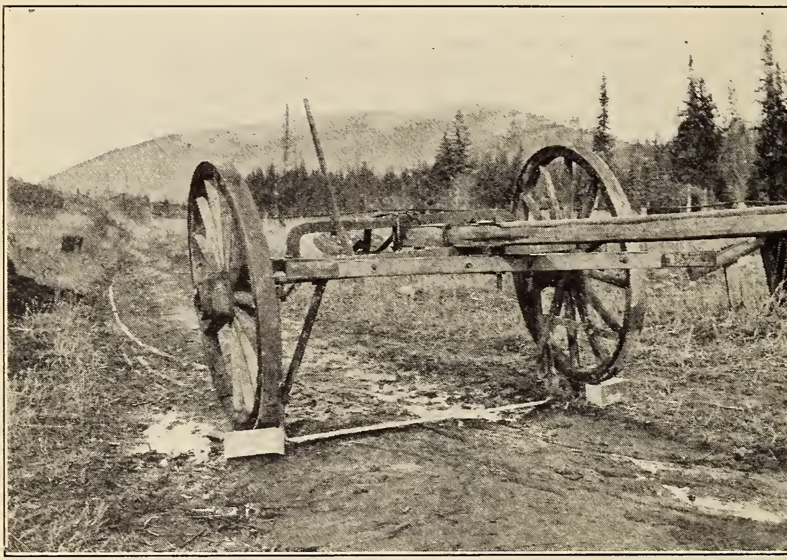

FIGURE 23.—The light underground root pruner used at Savenac nursery for pruning 1–0 stock

provided the density of the seedlings is not too great for third-year development.

Two types of implements have been developed at Savenac nursery to prune seedlings while in place in the seed beds, at any desired depth below the surface. The stock is commonly pruned at a depth of 4 inches because it is from that point down to 8 inches below the surface that development of a greater number of rootlets is desired. These devices prune the full width of the 4-foot seed beds in one operation. The lighter one of the two (figs. 23 and 24) consists of a flat steel blade one-fourth inch thick mounted on wheels. A lever operated from the driver's seat tilts the blade to give it a bite in the ground. When the blade reaches the depth to which it has been adjusted, it automatically assumes a horizontal position. The blade is mounted with one end slightly in advance of the other so as to give it a shearing edge as it is drawn through the beds. A team of horses can operate this implement in 1-year-old stock. The Smith digger is converted into a pruner for older stock. (Fig. 25.) The wedge-shaped lifting blade is removed and a thin flat blade substituted that

will sever the roots with the least disturbance of the seedlings. This implement is pulled along with a cable wound around a capstan revolved by one horse. Greater power is derived through this arrangement than with the lighter implement which has direct draft. Two-year-old seedlings can be pruned with the heavier machine. It is slow, but this is a decided advantage in stony ground, because the operation can be stopped to remove stones and other obstructions that lie in the path of the blade before considerable damage is done. Two men and one horse are required to operate this pruner and only 200 or less 4 by 12 foot beds can be pruned in a day, the number depending upon the length of the rows and the number of set-ups necessary. The lighter implement will prune 500 beds in a day, and is operated by one man and a team of horses. It moves along as rapidly as the horses walk, consequently if the blade strikes a stone or root, the blade is thrown out and a linear foot or two of seed beds damaged. With future pruning of the stock in view, the ground best suited for root pruning should be selected at the time plans are being made for new seed beds.

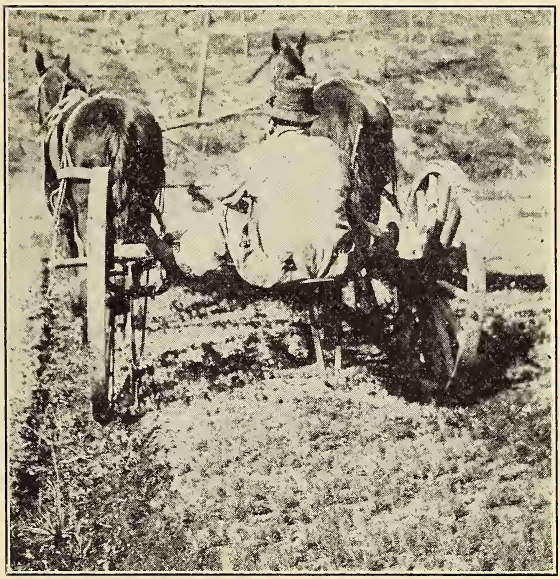

FIGURE 24.—Underground root pruner passing over and under beds of 1-year-old yellow pnie seedlings

The beds are sprinkled before the pruning operation to better bind the soil to the roots of the seedlings. After pruning the beds are again sprinkled to settle the soil about the roots.

In lieu of special underground pruning devices, a spade is sometimes used to cut off the roots of the plant while in place. The practice is limited to transplant rows and the edges of seed beds. The spade must necessarily be pushed in slantwise, resulting in irregular pruning. Some commercial nurseries add to this practice a thinning operation by removing spadefuls of seedlings in checkerboard fashion to increase the margin of seed-bed area that may be pruned with a spade and to provide greater room for additional root and top development.

TRANSPLANTING

The cost of transplanting has been so reduced at Savenac nursery by the improved methods developed there that the expense of getting the better stock is unquestionably within justifiable limits. Trans-

planting has the advantage over underground-root pruning that not only are the roots pruned but the spacing between the plants is widened and made more uniform, to the betterment of future top and root development.

The advantages of transplanting may be summarized as follows:

Through timely widening of the growing space it produces not only strong and sturdy but also uniformly developed roots and crown structure. It makes possible the pruning of the roots at any length desired, thus stimulating dichotomous branching.

It holds back dependably that deep and diffuse root development so difficult to remove with the tree and helps to build up a densely crowded, fibrous root system through the formation of short rootlets.

It renders feasible and makes cheaper the placing of the roots in the planting hole in a natural position and lightens the labor of the planting act in general.

SEASON FOR TRANSPLANTING

Ordinarily seedlings are transplanted in early spring or late fall when they are dormant. At Savenac nursery fall transplants

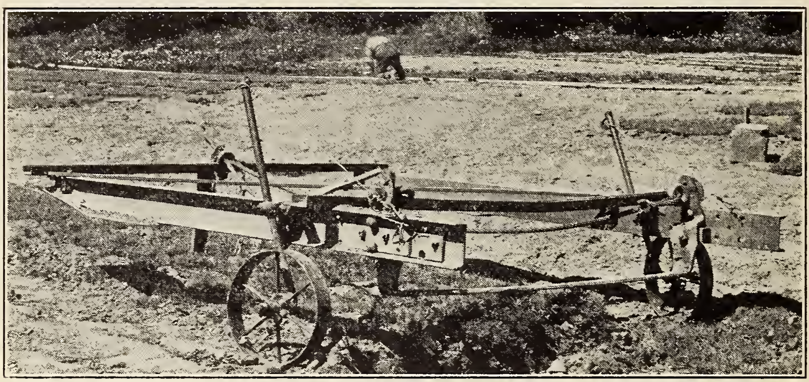

FIGURE 25.—The heavy underground root pruner used at Savenac nursery for pruning 2–0 stock

require mulch the first winter; if they are not mulched there is a heavy loss due to the trees being thrown out of the ground by frost in early spring. Without mulch this loss has been as high as 40 per cent.

Transplanting is possible at any time when the soil can be worked, even in midsummer. However, if it is done in hot weather, success is possible only through greatly increased vigilance in protecting the trees from the hot sun and drying winds during the operation and immediately following it. The percentage of loss incurred by transplanting under adverse conditions is naturally higher, or the cost of special care required to make the transplanting successful is proportionately greater.

Favorable conditions last long enough for the work to be done without the need of a large unwieldy crew. Savenac nursery transplants as many as 2,500,000 trees some years. This large program, including all phases of the work, can be completed by 15 people in twenty-one 8-hour workdays. Nevertheless, the best transplanting season is short, so the work should get under way as soon as the ground can be worked. Forethought in planning the work and

repairing all equipment before actual operations start is important, otherwise valuable time will be lost later.

SELECTION OF TRANSPLANT AREAS

Different species thrive on different kinds of soil; consequently better use of nursery ground is made possible by the proper selection of areas for transplanting. On a gravelly piece of ground western yellow pine will do better than the other species, whereas western white pine should be grown on better soil. If there is a piece of low ground that is moist during most of the year it should be used for Engelmann spruce and western red cedar.

Each block should be rectangular in shape to facilitate work during transplanting and other later operations.

Irrigation problems should be carefully considered at this time. Once the nursery has been divided into compartments and a definite plan made for irrigating, there will be little work on such problems from one year to the next. When the transplant acreage is small and the surface of the ground irregular, piped water is the most feasible plan of irrigation. When the area is extensive and level, and water plentiful, furrow irrigation is more practical. At Savenac nursery, the latter method of watering is used for the transplant beds. The main supply ditch follows one side of the nursery and is tapped at right angles by secondary ditches leading to the upper end of each compartment.

PREPARATION OF THE GROUND

Transplant ground requires thorough plowing and disking to put it in suitable shape for planting. With light, sandy soil it has been found best to plow in the fall and disk in the following spring. This treatment leaves the soil sufficiently loose for good root development, yet firm enough to work well with the transplant tools. With heavier soils, spring plowing and disking puts the soil in the proper tilth for immediate transplanting.

After disking, the surface is much improved by smoothing and leveling with a float. At Savenac, this device is made of three heavy 12-inch planks overlapping on the edges like three tiers of shingles inverted. This is dragged over the ground by a team of horses, the edges of the planks scraping the surface. The draft is placed a little off center so that the planks are drawn slantwise thus shearing off to the side little ridges of surplus soil. The soil is pulverized, the dead furrow filled in, and all small irregularities in the surface evened out in this operation. The area is then ready for the transplant crew.

SIZE AND AGE OF STOCK USED FOR TRANSPLANTING

Within certain limits small stock is more difficult to handle in transplanting than large stock, because the small plants can not be gripped securely by the transplant board, or tamped firmly in the ground without embedding them too deeply in the soil. However, the small plants overcome more quickly the setback caused by transplanting.

Seedlings with a combined length of crown and stem amounting to less than 2 inches are difficult to handle under the transplanting system used at Savenac nursery. Seedlings with a combined length of crown and stem over 4 inches become increasingly difficult to handle as the size increases. The large plants crowd the spacing allotted to each tree in the transplant board; the roots can not be uniformly pruned because when those on the larger trees are pruned to the proper length for transplanting the fine roots are cut off and nothing but a bare root stock is left; and the large plants require double the space in the transplant rows to allow ample room for two years of additional development, which obviously lowers by a proportionate amount the number transplanted in a given time. Seedlings with 1½ inches of crown and 1 inch of stem are ideal for transplanting. This is the average size of 1-year-old yellow pine grown at Savenac. Normal 1-year-old white pine and Douglas fir seedlings are slightly smaller, and 2-year-olds, when grown densely in the beds, slightly larger than the 1-year-old yellow pine. These are also easily handled in transplanting. Two-year-old Engelmann spruce and western red cedar are usually too small for handling conveniently in transplanting. Western larch is transplanted when 1 year old even though the seedlings are difficult to handle at this age. If they are left in the seed beds two years, their development becomes very uneven, some seedlings growing a foot high in that time and others barely 2 inches.

With two years of development in the transplant rows, these age classes attain the proper size for planting stock. The transplants put on very little growth the first year at Savenac nursery, and for that reason 1–1 and 2–1 age classes are seldom produced for planting stock. The small amount of growth the transplants make the first year does not warrant the cost of transplanting.

LIFTING AND PREPARING STOCK FOR TRANSPLANTING

Care should be taken that the surface of the seedling beds is not unnecessarily disturbed in loosening the trees; otherwise it becomes a time-consuming job to pull and arrange the trees in orderly bunches. The light underground root pruner described on page 48 loosens the seedlings very satisfactorily. After the blade has passed under the beds, severing the root systems, the seedlings remain erect. The spade and spading fork are used when it is necessary to resort to hand tools, but either is a poor substitute for the root pruner.

It is best to have each man pulling the stock work separately so that one will not interfere with another. It is unnecessary to count the stock; consequently large clumps with as many trees as the fingers can grasp, can be pulled with no regard to numbers. This enables the man to work fast, arrange the trees in orderly bunches, and get the trees out with little breakage because they lend support to one another when pulled in clumps. The dirt adhering to the roots is shaken free.

The trees are arranged in loose orderly bunches as they are pulled. Each bunch is heeled-in behind the worker with a handful of soil scooped over the roots and is thus protected from drying out until the trees are pruned and packed for the transplant crew. Ordinarily pruning and packing is done by one man, who follows closely behind

the tree pullers. The roots are pruned with a light cleaver and the seedlings placed between strips of moist burlap in long shallow trays. When filled, each tray is moved immediately to a shady place and covered with canvas. A tray holds about three thousand 1-year-old pine seedlings. A well-balanced crew can pull and pack in the trays about 30,000 trees per man per day, the number varying with the density of the stock in the seed beds.

To neglect root pruning when the trees are lifted is to defeat the principal purpose of transplanting. Proper pruning is important and fortunately simple. The small trees withstand a surprising amount of abuse at the time of transplanting provided they are

FIGURE 26.—Preparing the seedling stock for transplanting

kept reasonably moist. It has been found at Savenac nursery that roots of 1-year-old seedlings can be shortened to 2½ inches below the ground line without risking a high mortality in the stock. The severity of pruning is determined by the length and distribution of the roots desired in the stock when ready for field planting. When the development of a fibrous root system deep in the ground is desired the pruning is less severe, whereas a short, fibrous root system can be developed only by severe pruning. The branching of rootlets stimulated by root pruning and transplanting takes place from the points where the roots are cut, and the new rootlets go downward. Stock with 8-inch root systems and the bulky portion of root fibers from 4 to 8 inches down is desired for planting in northern Idaho and Montana. To get this development at Savenac nursery, the seedling roots are pruned to 4 inches before transplanting. If a bushy development of the root system is desired at 3 to 6 inches, the roots should be pruned to 3 inches before transplanting; and similarly, other zones of fibrous root distribution can be developed.

SIZE AND ARRANGEMENT OF TRANSPLANT BEDS

In most nurseries the rows of transplants are planted crosswise of the beds, and the beds are as wide as can be conveniently cultivated with hand tools, or as wide as the transplant boards are long, usually 6 feet. Such beds usually extend the length of the compartment but may be broken by cross paths. At Savenac nursery the transplant trenches are made with a horse-drawn plow; so the rows are continuous through the length of the compartments. Five rows comprise a bed.

The direction of the rows may be an important consideration in some regions. High soil-surface temperatures cause lesions in the tender stems of young plants, often resulting in the collapse of the stem at the ground line. This injury is commonly called stem girdle. By setting the seedlings in transplant rows running north and south mutual protection is afforded the young trees against the heating action of direct sunlight on the south side of the stems. Korstian and Fetherolf (*4*) found stem girdle on Engelmann spruce seedlings planted in rows running east and west. Subsequent experiments showed that the loss was greatest where the transplants inclined slightly to the north and that if the seedlings were inclined slightly to the south when transplanted, the ground was sufficiently shaded by the foliage practically to eliminate this injury. Losses that could with certainty be attributed to stem girdle have been only slight at Savenac nursery. There, the transplant rows run roughly north and south, but this is primarily to simplify irrigation.

When the rows are made lengthwise of the beds, each bed should contain an odd number of rows, 5, 7, 9, etc. With even-numbered rows, an extra trip is required to cultivate the outside of the last row. At Savenac nursery the beds are only five rows wide so that the water from the irrigation furrows on either side will penetrate to the center of the beds overnight.

Sufficient space is left at the ends of the beds to allow turning room for horses and implements.

Spacing

There is a decided advantage in getting as many trees as possible to the acre notwithstanding the fact that a wider spacing may prove somewhat more satisfactory in setting out the trees. The costs of weeding, cultivating, and watering increases proportionately with the greater area used. With the hand trencher the rows can be made 4 inches apart, but this is too close for the best development of the trees, and cultivation becomes practically impossible. Six-inch spacing between the rows permits the use of wheeled cultivators and does not crowd the plants. Eight inches between the rows is about the closest spacing that permits of work with the trencher plow used at Savenac nursery.

Unless the stock is exceptionally large when transplanted (such as 2-year-old western yellow pine) the trees are spaced 1⅓ inches apart in the row. This spacing is a trifle less than that commonly used at other nurseries, but no ill effects from crowding have been apparent.

Table 7 shows the number of transplants per acre for different spacings with the irrigating system used at Savenac nursery.

TABLE 7.—*Number*[1] *of transplants per acre*

Space between rows	Spacing in rows	Transplants per acre	Space between rows	Spacing in rows	Transplants per acre
Inches	*Inches*	*Number*	*Inches*	*Inches*	*Number*
6	1⅓	549, 000	8	1⅓	460, 875
6	2⅔	274, 500	8	2⅔	230, 438
7	1⅓	501, 750	10	1⅓	397, 875
7	2⅔	250, 875	10	2⅔	198, 938

[1]Allowing 18 inches for irrigation furrows every 5 rows

MAKING THE TRANSPLANT TRENCHES

There are two distinct types of transplant trenches; V-shaped and furrow. The former is made by compressing the soil with some

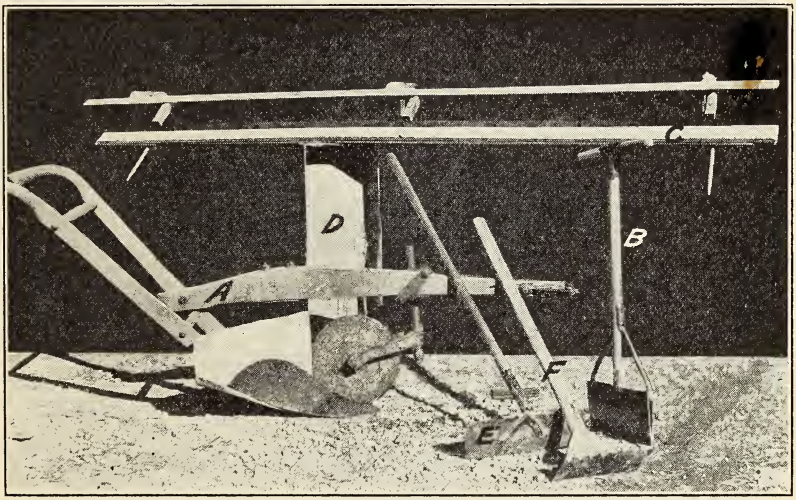

FIGURE 27.—Transplanting tools used at Savenac nursery: A, Trenching plow; B, Mast trencher; C, transplant board; D, seedling packet; E, trench hoe; F, transplanting rake

wedge-shaped tool and the latter by throwing out the soil with a plow or spade. Hand trenching by either method is expensive, amounting to more than 25 per cent of the total cost of transplanting.

V-SHAPED TRENCH METHOD

The Mast (*5*) trencher (fig. 27, B) is commonly used in this country to make the V trench. This tool is constructed of two steel plates, 7 inches wide and 26 inches long, welded at one edge and drawn out to a thin edge. The opposite edges of the plates are spread about an inch apart, to form a wedge. A section of pipe about 2 feet long with a T handle is riveted and braced to the wedge. The completed tool resembles a crude snow shovel. It weighs about 20 pounds.

It is forced into the soil by pressure of the foot on top of the blades. Moving the handle to and from the body works the wedge

into the soil to the depth desired. The implement leaves a trench 3 to 4 inches wide at the top with smooth tapering sides meeting at the bottom. (Fig. 28.)

This implement is impractical in heavy soils, as it can not be forced to the depth desired for a transplant trench. In very loose soils,

FIGURE 28.—V trenching with the Mast trencher at Savenac nursery in 1913

which will not hold a vertical wall in a furrow, especially soils with much humus, the implement is indispensable.

Soil is brought into contact with the roots of the transplants by tamping together the compact walls of the trench. Later the planted trench is more tightly closed by pressure from the trenching tool when the next trench is made. In the V trench the roots are spread out in a thin plane and especially in heavy soils future development of the root systems continues in that form until the trees are removed

from the transplant rows. Under these conditions the trees do not avail themselves of the space between the rows but crowd one another. One result is tangled roots that are difficult to separate when the stock is sorted for shipment. Obviously the spacing in the transplant rows should be wider in this type of trench and the distance between the rows may be less, than under conditions where concentric root systems develop. A concentric root system is desired in stock that has attained the proper size for field planting in order to give it anchorage on all sides.

At Savenac nursery damage from frost heaving has been greater in the V trench than in the furrow trench. Under frost action the V trench opens at the seam where the walls were previously pressed together, sometimes extending the full length of the row. The fan-shaped root systems offer little resistance to the force of the frost and fairly pop out of the ground.

Before the furrow-trench method was adopted at Savenac nursery, numerous attempts were made to devise some horse-drawn implement that would make a V trench. A rolling disk with convex sides seemed the most feasible plan, but experiments showed that a great deal of weight was necessary to hold the disk to the desired depth in the soil, and such weight necessarily required a wheeled implement to balance the load. This proved impracticable because one wheel often obliterated a planted row while the other ruined the unplanted area with deep ruts and packed soil. A gang of five disks without a wheeled carriage was tried, but the disks could not be forced deep enough into the soil. Other modifications of the disk idea were tried, including small plowshares and corn shoes placed before the disks to cut the trench for the form molding disks behind, but none proved satisfactory.

The Furrow-Trench Method

The furrow type of trench is also called the open trench, and that describes one of its principal advantages over the V trench. It is open on one side, enabling the planter to see the position of the roots of the trees dangling from the transplant board before they are covered with dirt.

A furrow trench is made with either a spade or a small plow. It is important that the loose dirt be thrown no great distance from the trench, otherwise the planter will have difficulty in reaching it when refilling the trench. The land side of the trench must be vertical and clean-cut to give support to the roots of the trees when the loose dirt is thrown against them from the open side.

One of the greatest savings in the whole transplanting operation at Savenac nursery has been effected by using a small 7-inch plow to make the trenches. With a steady horse to draw the plow, the foreman of the transplant crews is able, aside from his other duties, to open enough trench to keep five crews busy. In other words, one horse costing about $1 a day supplants the labor of five men, the number formerly required to do the same amount of trenching by hand, either with a spade or a Mast trencher.

There are a few objectionable features of the plowed trench. The rows can not be made as straight as with a hand tool. This is rather disconcerting to a nurseryman at first because he has been accus-

tomed to straight rows, and the first rows made with the plow are more crooked than those made later, when experience has been acquired with the new system. However, curving rows are a matter of appearance only and in no way affect the nursery operations. A more serious objection is the necessarily wide space between the rows. It is impractical to put them closer than 7 inches with a plow and 8 inches is usually needed in practice. This spacing uses one-third more area than is necessary with the hand-trenching methods, but on the other hand, cropping and its consequent drain on the soil fertility is less intensive so that the wider spacing can not be considered a complete loss. Turning room for the horse must be left at the ends of the rows. If this space is not required for entrance to the area for other purposes the rows can be extended to the ends of the compartment with hand-trenching tools. It is impractical to trench small areas less than 100 feet in length with a plow.

FIGURE 29.—Method of opening trench with a plow

PLOWING THE TRENCH

At Savenac nursery the following system of plowing the furrows is used so that the trenching will not interfere with the planted trees. (Fig. 29.) Since a new furrow can not be opened until the one alongside has been planted, this system is necessary in order to keep the trenching sufficiently in advance of the planting.

A string is stretched the full length of the rows. The plow makes a round trip, one way on each side of the line, making furrows about 18 inches apart. (See note Table 7.) This allows room for an irrigation furrow between the beds. The dirt from the plow is thrown from the two furrows in opposite directions and away from the string. When these two furrows are planted, another round trip is

made, and so on, each new furrow being 8 inches from the furrow made on the same side of the string on the previous trip; and as on the first trip the plow throws the dirt away from the string and away from the planted rows. While the last two rows in the set of 10 are being planted, the string is moved over the proper distance (about 8½ feet) and a new set of rows started.

The trench must have a vertical and clean-cut land side, and the loose soil should be thrown no great distance from the trench. These results are obtained by a few simple alterations and attachments to a small 7-inch plow. (Fig. 27, A.) A 14-inch rolling coulter attached to the plow beam will cut through the fine roots and other débris that would otherwise collect on the plowshare and break the vertical wall. The trench is kept narrow by reducing the plow-point to 4 inches in width. The moldboard is cut to 10 inches to reduce the distance the soil will be turned out from the trench. A

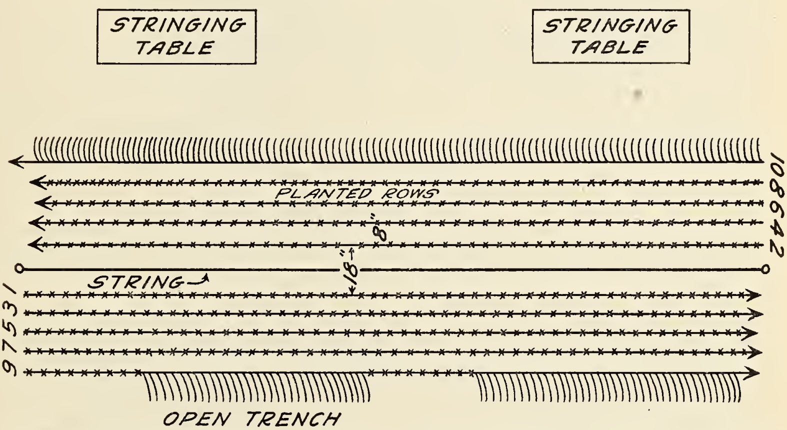

FIGURE 30.—The plowed trench. The man is using a wide hoe to lift out lumps of soil that have rolled back into the trench after plowing

wing of heavy sheet iron is attached to the moldboard extending back but parallel with the land side, and twisted over to mold the loose dirt in a roll so that it will not slide back into the trench.

After the plow has made a furrow, the foreman, with a tool constructed especially for the purpose, cleans out any loose soil that has rolled back into the trench and straightens sharp kinks or broken walls. The tool is fashioned like a hoe, but it has a shorter handle and a blade 2 feet wide. (Figs. 27, E, and 29.)

STRINGING THE TRANSPLANT BOARD

With a transplant board, 75 seedlings can be planted simultaneously. Filling these boards with the seedlings preparatory to planting is called stringing or threading.

The Transplant Board

The transplant board consists merely of two strips of wood closing together like the covers of a book, between which the trees are clamped. The upper part of the stem and the tops are held between the strips, and the roots extend out from the closed edges, so that

they can be set up in the trench, covered, and firmly tamped without the board interfering. After the soil has been tamped about the roots the trees are held firmly in the ground so that the board can be opened and the tops released, leaving a row of 75 trees planted as well as if the trees had been set out individually.

The Savenac nursery board (fig. 31) has evolved from the Yale board, but because of the numerous changes that it has undergone, the orginal model can hardly be recognized. For one thing, the principle of gripping the seedlings is different. The top strip of the Yale board falls above the notches, placing the pressure on the crowns of the seedlings, whereas the Savenac board exerts its pressure below the notches on the stems of the seedlings. This, even though the pressure is not the same on all of the trees—as is often the case when a number of large trees in the board hold the pressure from the

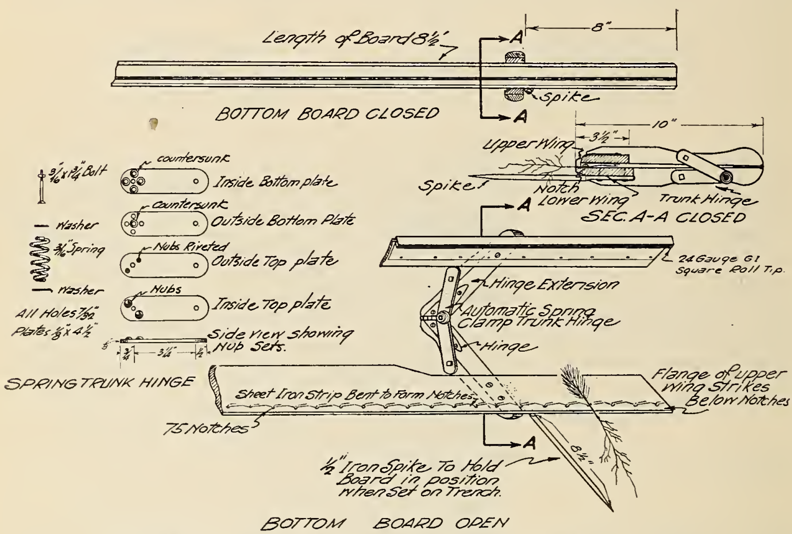

FIGURE 31.—Details of the Savenac nursery transplant board

others or the board becomes slightly warped—the bulky tops can not work through the board when it is being carried to the trench.

Another big improvement was made by forming the lip on the upper strip with light-gage galvanized iron and incasing most of this wooden strip with metal. The numerous angles made in this light sheet iron to form the lip give it the rigidity of much heavier metal and eliminate warping, in spite of the fact that these transplant boards are longer than any known to be in use elsewhere. Such boards have been serviceable after 10 years of hard usage.

The notches for spacing the seedlings in the board are formed with a metal ribbon one-fourth inch wide tacked to the bottom strip of the board. These have proved more substantial than wooden notches.

Trunk hinges have replaced the thumbscrews to exert the pressure that grips the seedlings when the board is closed. These same hinges are double-acting and hold the board open at an angel of 45° while the stringer is filling it.

Two spikes attached to the back of the board hold it in position on the edge of the trench while the planter covers up the roots. (Fig. 32.)

The Stringing Table

It is also necessary to protect the seedlings from drying winds and the sun while they are being placed in the transplant boards. A table of convenient height at which the stringer can work is also

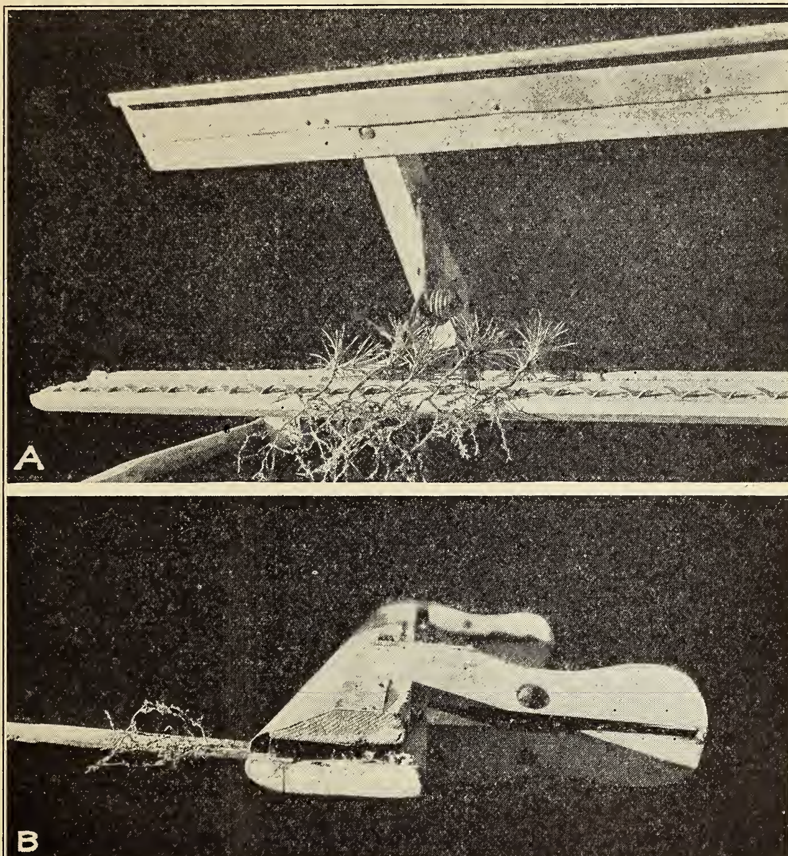

Figure 32.—The Savenac transplant board: A, open; B, closed

important to the efficient handling of the job. Various contrivances must be at hand. These requirements can be met by framing in the table and covering the frame with canvas on the ends, the back, and the top. The front is left open or has canvas flaps to give the planter access to the table when changing boards. The stringer works between the table and the back wall. Two shelves one above the other about 15 inches apart, comprise the table. One shelf contains the board that is being filled and the other is in readiness to receive the empty board from the planter. Thus there is no confusion when the boards are changed. The lower shelf is of con-

venient height for the stringer to reach from the ground. The upper shelf is conveniently reached by standing on a bench hinged to the front legs of the table and elevated about a foot from the ground. When the stringer steps from the plank to work on the lower shelf this plank is lifted out of the way by two coiled springs. (Fig. 33.)

The transplant tables are made of light material so that two men (the planter assigned to each table and the foreman) can, as the work progresses, move a table to the next set-up.

Stringing

The stringing operation sets the pace of the whole transplanting job. The foregoing paragraphs have described equipment that has been designed to speed up this operation. There are other considerations. The stringers should be nimble-fingered. For this reason girls are employed at Savenac nursery to do this work. Some boys are fast stringers, but old men are not. Because stringing is con-

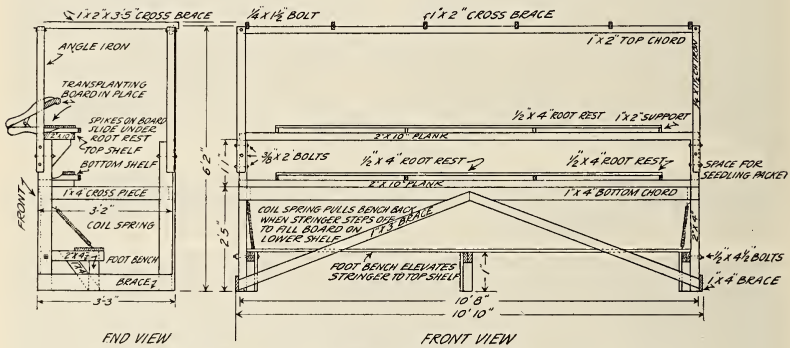

FIGURE 33.—Details of Savenac stringing table

sidered light work it is often assigned to old men who for one reason or another are retained in the nursery crew. It would be far better to have them do other work where their efforts affect only themselves than to take part in an operation such as transplanting where several individuals form a unit for production.

The length of the Savenac nursery transplant board was determined by stop-watch studies of the number of trees that could be placed in the board at a high rate of stringing in the time that a boardful could be planted. The object of this was to coordinate the efforts of the stringer and planter. The result was a board 8½ feet long containing notches for 75 trees. The fine coordination of stringing and planting is, of course, lost if slow planters are assigned to fast stringers and vice versa.

Competition between the crew units is an inducement to higher accomplishment, but enthusiasm will eventually lag and the workers grow listless. A greater incentive is necessary. A piece-rate basis of pay, or a graduated scale of bonuses for high production, supplies the needed incentive.

The following sliding wage scale has been used with excellent results. The stringer and planter received like amounts.

Average number of boards per hour for the day:	Basic rate per day
36 or less	$2.75
37	2.80
38	2.85
39	2.90
40	3.00
41	3.05
42	3.10
43	3.15
44	3.20
45	3.25
46	3.30
47	3.35
48	3.40
49	3.45
50	3.50

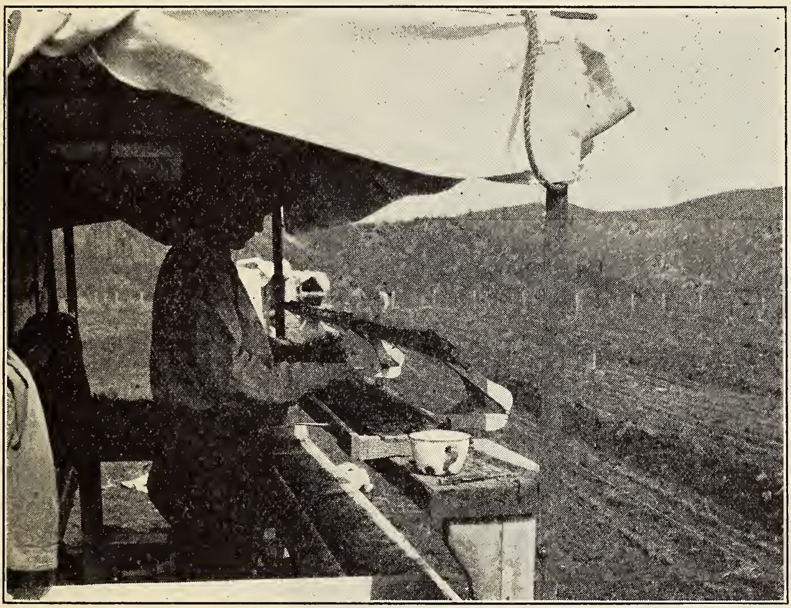

FIGURE 34.—Stringing seedling trees for transplanting. The stringer is standing on a bench and filling the transplant board on the top shelf. The transplanter is planting the board that will be returned to the lower shelf before the upper one is finished

The stringer starts at one end of the board, placing a seedling in each notch with the fingers of one hand and holding a supply of seedlings in the free hand. When she has reached the end of the board she closes it with a tap on the top strip and steps up on or down from the foot bench to the right level for stringing the other board, which has meanwhile been returned by the planter for refilling and placed open and in readiness to string. The stringer grabs a fresh supply of trees from a packet conveniently placed at the end of the table and starts stringing the second board in the opposite direction from the first. Thus the work is a continual merry-go-round of stringing, with necessity for only a few quick motions that do not pertain actually to placing the trees in the notches. (Fig. 34.)

The stringer sees each individual seedling as it is placed in the board; therefore to her is assigned the responsibility of culling out any seedlings unsuited for transplanting. Mutilated and dead plants are left in the notches and good ones placed on top. This action is quicker than removing the dead plants. Diseased and deformed plants are brushed off the board and good ones placed in their stead. A card with mounted specimens of poor stock hangs in each table to guide the stringer.

USE OF THE TRANSPLANT BOARD

Short, stocky young men as a type make the best planters. The work is strenuous, requiring a strong physique, and there is much stooping, which gives the men of short stature a decided advantage.

FIGURE 35.—Setting the transplant board

In setting the board (fig. 35) the planter faces the open side of the trench to enable him to see the position of the dangling roots. The board should be vertical and closely joined to the previously planted trees. It should rest on the edge of the trench with the roots and stems pressed against the vertical wall of the trench. To tilt the board will cause the stems of the trees to develop a sweep that makes them difficult to plant when they have developed into planting size. The spikes on the board are pushed into the soil to keep the board in position when the planter releases his hold. He then starts at one end of the board, straddles it, and rakes the loose soil back into the trench as he moves forward. His feet at the same time are kept busy tamping the soil on both sides of the board. (Fig. 36.) A short-handled hoe with a blade 12 inches wide is used to rake in the loose soil. He repeats the operation, going back the length of the board, raking in additional soil missed the first time, and tamping it firmly against both sides of the roots. A third trip is made on the front side of the board, during which the planter presses down high piles of soil that will interfere with opening the board. The

planter completes the tamping operation at the beginning of the open trench and drops the hoe where it will be in readiness for the next board. He opens the board, raises it, and carries it *open* to the stringing table, where he places it on the empty shelf in readiness for filling and removes the full board to plant it.

The planter should not be required to walk any great distance from the table to his trench. His section of rows should be about 10 boards long (85 feet), and the stringing table should be placed midway between the two ends. The table should face the rows and stand at the edge of the 10-row section being planted. Before a new set of beds is started the foreman and planter move the table back on new ground the distance required for 10 rows.

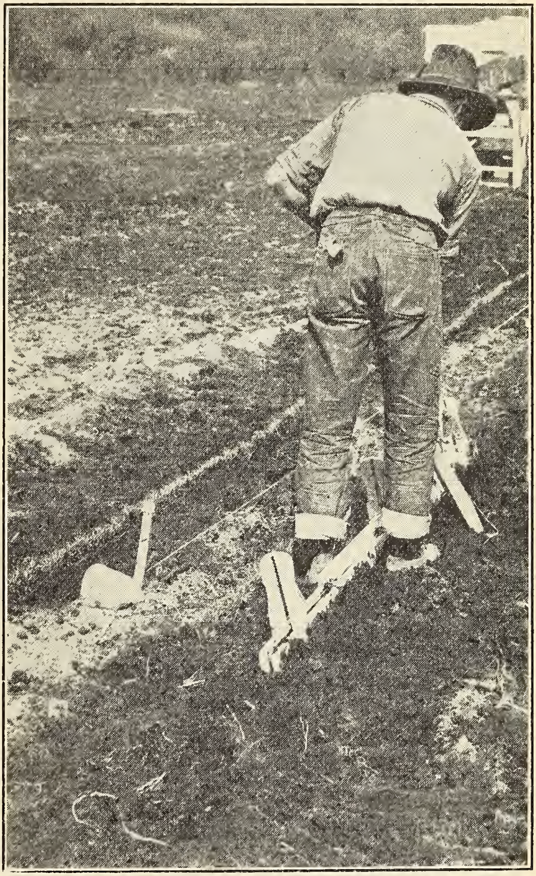

FIGURE 36.—Planting the transplant board filled with seedlings

CHECKING THE QUALITY OF THE WORK

In planning this system of transplanting, every endeavor has been made to make it foolproof. Contrary to first impressions that high speed in this sort of work will result in poor work, a very high survival is generally obtained. Eighty-five per cent is very common, and 95 per cent is occasionally attained. Each planter works in his own section, so he is responsible for the work in that section. Aside from inspecting the actual planting operation, the foreman can check the alignment of boards, the tamping, and the depth of planting at any time after the trees are in. If the trees are poorly placed in the boards, the planter complains to his stringer because the planting is made more difficult.

KEEPING A RECORD OF OUTPUT

The actual number of trees transplanted can be easily kept, even for each individual crew. Since each planter has a section of rows

of a given length, the daily output can be computed by counting the rows, converting their length into boards, and then multiplying by 75—the number of trees in a board. Sometimes one crew gets a little behind. If this crew can not keep up with the others, the section should be shortened and that of the best crew increased a corresponding amount. If one crew for some reason or other gets behind only temporarily, an adjoining crew can help with the necessary number of boards so that the trench can be filled from one end to the other before a new one is started. Small pot labels are used to mark off any such boards planted by one crew in the section of another. Later these are counted and the proper credit and deductions made for the crews concerned. When the transplant operation is run on a piece-rate basis of pay, accurate accounting of the output of each crew is, of course, necessary.

SPEED ATTAINED

The record for transplanting at Savenac nursery is 60 boards an hour maintained for two hours by a crew of two. This is at the rate of 36,000 trees per 8-hour day. The average expected of a crew of one stringer and planter is 24,000 trees per day. With the foreman's time distributed over five such crews the average for each person engaged in transplanting is about 11,000 trees per day. The average cost of transplanting at Savenac nursery is 87 cents per thousand. (See Table 9, p. 90.) This cost includes all current items going into the operation, such as lifting and preparing the seedlings for transplanting, preparing the ground for transplanting, stringing, and transplanting, and the foreman's time.

THE TRANSPLANT FOREMAN'S DUTIES

The foreman is indeed a busy man when handling a large transplanting operation. Aside from supervising the work, he plows and cleans the trenches, keeps the stringers supplied with trees, helps to move the tables, keeps the equipment in repair, and even serves as water boy to the thirsty planters. Then, if his time is not all taken up, he makes the irrigation furrows between the planted beds.

CARE OF TRANSPLANTS

Watering

The making of irrigation ditches closely follows transplanting, so that water can be turned in on the day's work when the transplanting crews leave in the evening. (Fig. 37.) Shallow furrows are made with a hand cultivator or a round-pointed shovel.

Stones and other débris unearthed by the transplant plow are carried away before water is turned into the irrigation furrows. Any other work, such as uncovering trees set too deeply, is not allowed to accumulate, because once the water is turned on the area, and for several weeks thereafter, the loose, wet soil can not support the workmen but becomes a mire when trampled. For the same reason precautions should be taken that the overnight irrigating does not reach ground that is to be transplanted the following morning. (Fig. 38.)

A novice at irrigating commonly turns on too much water in the furrows at the start. New furrows absorb a great deal of water, and he becomes impatient to get the water through. The gradient of new

furrows is apt to be irregular, so the irrigator must follow the water in each furrow to scoop out the high places and build miniature levees over the low ground. Should the water flow too fast, it will dam at the high points and break through on the sides, flooding the

FIGURE 37.—Irrigation follows closely behind transplanting. The beds to the right are uniformly moist. The two beds to the left of these are being irrigated, but moisture has not reached the centers. Furrows to the left have not had water turned into them

low places. Once the water has been carried through the furrow, but little attention is necessary. At Savenac nursery water is carried from the main ditch across the upper end of the transplant rows of each compartment. This supply is tapped by drilling a hole in

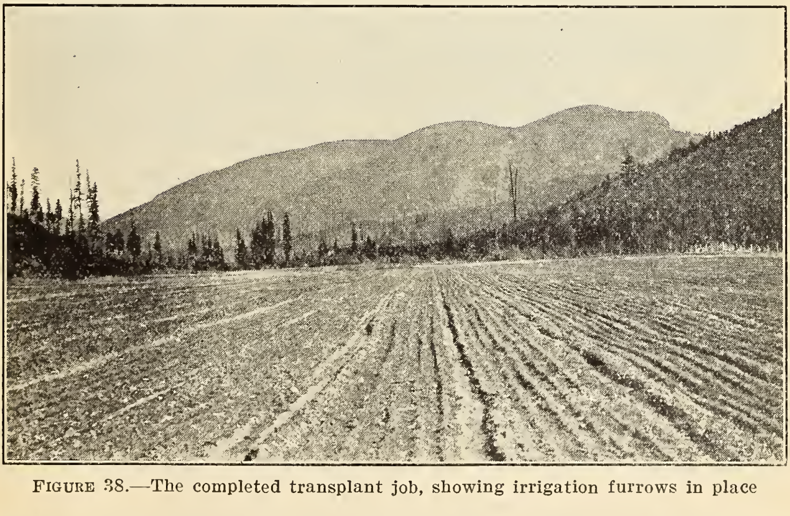

FIGURE 38.—The completed transplant job, showing irrigation furrows in place

the flume over each furrow. Water flowing through a ½-inch hole from the flume gives sufficient volume for each irrigation furrow in a field 400 feet long.

The nurseryman can safeguard against washing of the soil by lowering the water over steep places through drop boxes.

The frequency of watering, of course, depends upon the condition of the soil and the current weather. It also varies with different soils and during different periods of the year. Furthermore, the ground is more thoroughly soaked by furrow irrigation than by sprinkling; consequently the applications by the former method may be less frequent. During the hot, dry period of July and August the irrigation of transplants is necessary only once a week at Savenac nursery.

Weeding and Cultivating

Cultivating is done with hand cultivators. (Fig. 39.) The weeds between the trees in the rows must be picked by hand or taken out by means of hand-weeding tools.

MULCHING

In this region transplants do not ordinarily require mulch, because abundant snowfall spreads a protective blanket over the trees during

Figure 39.—Cultivating transplants with a hand cultivator

the coldest period. However, spindling trees, especially western white pines taken from dense seed beds, lack proper root development the first year in the transplant beds to withstand the frost heaving in late fall and early spring. Loss from this cause can be prevented by a light straw mulch spread over the transplants in early fall and removed after frost danger has passed in the spring. Frost-heaving damage has also been prevented without mulching by leaving the last crop of weeds in the transplant rows. The weeds serve as a mulch to a limited extent. The seeds are not matured in this last crop of weeds; and no ill effects from this practice have been noticed.

ESTIMATING THE STOCK

The natural tendency is to overestimate the amount of stock on hand unless the samples for counting are mechanically selected. It

is especially difficult to select beds of average density when one extreme is represented by beds of sparse growth such as results from cutworm injury, and the other extreme by beds of exceptionally good stocking. By taking a large number of counts on small areas at regular intervals throughout the blocks of stock a reliable estimate may be arrived at.

For seedling-stock estimates at Savenac nursery a frame 6 inches wide and 5 feet long (inside dimensions) is placed across a bed and the seedlings within the frame counted. The frame is longer than the width of the bed to allow for any seedlings found outside of the margins of the 4-foot beds. The count, however, is considered the stocking for 2 square feet or one twenty-fourth of a 4 by 12 foot bed. For rows of seed beds 48 to 100 feet long, one count is taken in each row, near alternate ends. The frame is not placed at the extreme end of a bed, for there the stand is ordinarily ragged, but is placed the length of the frame from the end. Thus, the selection of each sample is mechanically made. For rows of beds more than 100 feet long, sample counts are also taken from the centers of the beds. Weak or deformed seedlings that will very likely be culled when the stock is removed for transplanting or shipping are deducted in the count. The average of all the sample counts is the average for 2 square feet, which when multiplied by one-half the seed-bed area in the compartment gives the total stocking.

For estimating transplants a stick the length of the transplant board (8½ feet) is used. This is placed on a row of trees and the number living in the length of the stick counted. Ordinarily the estimator starts in one corner of the field and works diagonally across it, taking a count on the first row in the first bed, second row in the second bed, and so on until he has crossed and perhaps recrossed the field. An average of his counts will give the average number living per board planted, from which the percentage is computed. This is applied to the number of trees planted, which will be found in the record of the transplanting operation.

STOCK DISTRIBUTION

PREPARING STOCK FOR SHIPMENT

Unlike the ordinary business dealing in production, the Forest Service nursery is not concerned with sales. It has a definite plan for disposing of its stock even before the seeds are sown. The scheme of things is somewhat like growing definite amounts of certain species and age classes under contract for future deliveries. In short, the demand is fixed before the production of the supply is started.

There is another circumstance that plays an important part in stock distribution at Savenac nursery. Ordinarily the season's shipments are directed to not more than four points. The stock is shipped in lots ranging from 20,000 to 50,000 trees. Seldom is a shipment made up of more than two different species or age classes. From this it can be seen that the shipping work is comparatively simple; and because each order deals with large numbers and few varieties special heavy machinery and expensive set-ups for lifting the stock are really practical.

JUDGING THE QUALITY OF THE STOCK

There are, of course, certain adjustments necessary before the stock is definitely allotted to the various planting projects. Some blocks of stock may have failed to attain the proper development in the period originally intended, on account of poor soil conditions or crowded seed beds or for other reasons. In such cases an oversowing of several hundred thousand carried in reserve becomes exceedingly useful for replacement of the underdeveloped stock, which automatically becomes the reserve the following year.

The selection of stock should be made as soon as the growing season has advanced far enough to indicate the final condition of the stock for fall and spring shipments. In judging stock, too much weight should not be placed on the appearance of the stock above-ground. The tops are but half of the plant and the least important half from the standpoint of good stock for field planting. The condition of the root systems—whether spindly or strong, wiry or bushy—is an important point to consider in judging the stock. The balance, or relation in size between top and roots, is also important to the survival of the trees. (Fig. 40.)

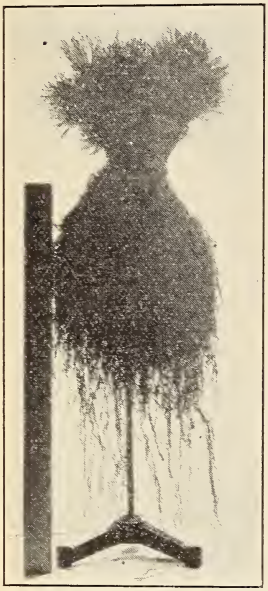

FIGURE 40.—One hundred 1–2 western white pine of planting size, before pruning but otherwise ready for shipment. The balance between roots and top, in so far as bulk is concerned, is more clearly shown in bunches of trees than in individuals.

A thorough examination should also be made at this time to discover any possible disease among the plants.

AGE AND SIZE CLASSES

Soil fertility, temperature, and length of growing season play an important part in the development of plants. The age at which the tree can attain the best development for planting out in one region may be entirely different from the best age in another region. Furthermore, the development of the stock will vary from year to year in the same region. In some regions nursery stock becomes too large if held more than two seasons; in others it requires three or even four years for proper conditions. Thus, age classes are merely convenient expressions of size classes for stock grown in a particular region. These age classes denote the years required in seed beds and transplant beds to produce the greatest number of uniformly good plants of a certain size. It is futile to attempt to apply age-class studies of one nursery in another nursery operating under different climatic conditions. It can be said that 1–2 western yellow pine stock as grown at Savenac nursery (meaning well-balanced plants with 8-inch roots and 6-inch tops) is best for western Montana planting, but unless the age class is interpreted to size class it has no application on the west coast, or in the South where 1-year-old yellow pines, such as *Pinus taeda*, are a problem to handle because

of the large size attained under the more favorable growing conditions of that region. Table 8 shows the age of different species, both in the seedling and transplant classes, when ready for shipping from Savenac nursery.

TABLE 8.—*Ages of shipping size classes of trees at Savenac nursery*

Species	Seedling stock			Transplant stock		
	Time in seed beds	Time in trans-plant beds	Approx-imate height	Time in seed beds	Time in trans-plant beds	Approx-imate height
	Years	*Years*	*Inches*	*Years*	*Years*	*Inches*
Pinus monticola	2	0	4	1	2	5
Do	3	0	6	2	2	6
Pinus ponderosa	2	0	6	1	2	8
Picea engelmanni	3	0	3	2	2	3
Do	4	0	4	2	3	4
Thuja plicata	3	0	3	2	2	3
Pseudotsuga taxifolia	2	0	3	2	1	4
Do	3	0	4	2	2	6
Larix occidentalis	2	0	2–8	1	2	4

Western white pine and Engelmann spruce can be held over an extra year without becoming too large or top heavy for field planting if grown in the age classes indicated in Table 8. This makes it possible to take care of an oversowing of white pine by leaving some of the stock a year longer in the seed beds, provided the stand is not too dense, or by transplanting the excess stock when 2 years old.

In this region the expense of setting out the stock in plantations is twice the cost of raising the stock. It is well, therefore, to withhold doubtful stock from shipment, and it is real economy to throw away poor stock rather than send it out to be planted.

HARDENING OFF

A month before the stock is shipped in the fall the amount of water supplied the trees should be gradually reduced and finally artificial watering entirely stopped two weeks before the stock is lifted. This enforced drought tends to equalize conditions between the nursery and the field, and consequently to reduce the shock to the plant in changing its environment. Curtailment of watering retards the plant growth, causing the tissues to harden, the winter buds to mature, and the plants to go into the dormant state.

LIFTING NURSERY STOCK

HAND LIFTING

A spade is preferred to a spading fork for lifting stock of shipping size. The trees are deeply rooted, and it is desirable to save as much of the roots to a 10-inch depth as is possible with a minimum of stripping. An ordinary spade can cut the roots on all sides, but not at the bottom unless the blade is forced in slantwise. Driving the blade slantwise is not recommended, because in tapering off the root system the lower laterals are greatly reduced, and too much of the

root system is lost. If the spacing between rows is 10 inches or less, spading done vertically on the outside of the beds and between each two rows serves the same purpose as spading on both sides of each row. It is therefore better to spade all the rows in a section of the bed before pulling out the trees than to spade and pull a row at a time, because in pulling a single row the worker's feet or knees will firm the partially loosened soil on the next row, and it will need to be spaded on both sides to become properly loosened.

The spading fork does not cut the roots, but tears them out with the clump of soil that is removed. Tearing of roots, especially lateral roots securely anchored, should be guarded against, for the damage done to the plant is often greater than a cursory examination will reveal. These laterals commonly tear off at the main stem of the root system and remove with the heel a long strip of root cambium. The scar is immediately besmeared with the soil, and the damage passes unnoticed by the men pulling the stock.

Lifting and pulling are two entirely different types of work, and men best suited for each should be selected. Digging requires strong arms and legs to get the spade to the proper depth—8 inches or more. Pulling requires nimble fingers to count and tie the small trees, and a quick eye and thorough understanding of good stock to appraise those suitable for planting and those to be culled.

Special Lifting Devices

The Feigley tree lifter, an implement that may be purchased on the market, was tried to lift transplant stock at Savenac nursery. This device consists of an L-shaped blade attached to a heavy plowbeam, drawn by two horses in tandem. It proved, however, unnecessarily heavy for small trees; and guiding two horses and a plow in tandem along the rows proved to be a rather difficult feat for the ordinary teamster.

A 2-foot wide L blade, patterned after the Feigley tree lifter, was tried to prune and lift seedlings of shipping size from the seed beds. It seemed possible to get under the entire 4-foot bed with this device by undercutting from the paths on both sides. This proved impracticable, however, because the draft could not be centered from the path where the horses walked, and the blade promptly worked out of position.

Until the sturdier and more efficient Smith digger was adopted, the small tree lifter shown in Figure 41 did the work very satisfactorily in transplant stock. To the frame of a 1-horse cultivator is attached a U-shaped blade made from a ¼-inch steel tire of a wagon wheel. Several holes drilled at both of the upturned ends of the blade permit adjustments for the various depths of digging desired. Two shanks, from the old cultivator blades, brace the U blade. For large stock, a blade 10 inches wide is used to cut under a single row of transplants. Smaller stock, such as 1–2 white pine, is lifted two rows at a time, with an 18-inch blade. When this implement is used in the heavier soils at Savenac nursery or the blade is adjusted to go below 8 inches in the ground, iron bars are bolted at right angles to the bottom of the blade to elevate and thus loosen the roots of the trees in the ribbon of soil that is cut out by the blade.

Ordinarily these attachments are unnecessary because the movement of the blade alone jars the light soil from the roots so that the trees can be pulled out easily by the men. One horse draws the implement. This light implement is especially suited for small nurseries and for lifting transplants in short rows and in small lots from widely scattered parts of the nursery. It is not as efficient as the Smith digger for the more common large-scale operations where acres of transplants are progressively lifted.

The Smith digger, developed for lifting transplants set in crosswise of the beds, has been adopted at Savenac nursery for lifting shipping stock from the seed beds. (Fig. 43.) This device has a heavy rectangular steel frame that straddles the bed and slides on the

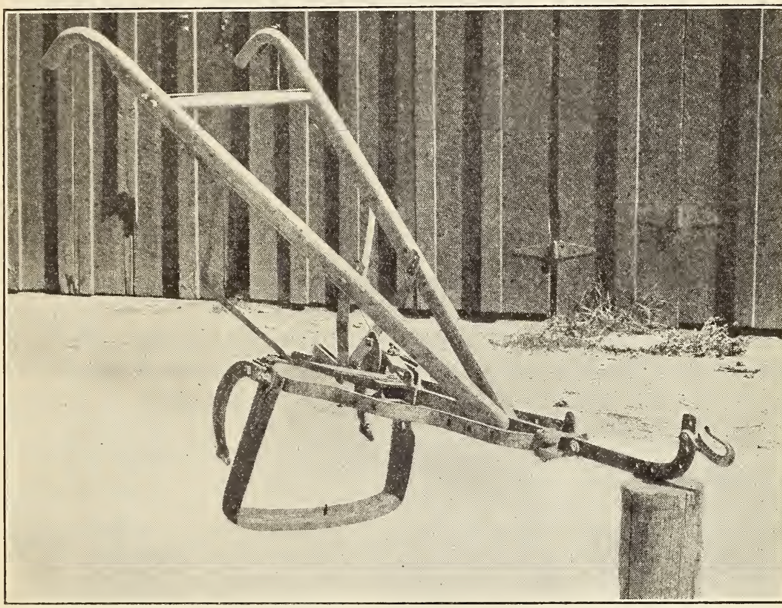

FIGURE 41.—A light tree lifter that does satisfactory work with small transplant stock

two paths on both sides. A thick wedge-shaped blade formed by bolting together two plates of steel at an angle of about 30° is underslung to the rear end of the frame. This blade severs the roots and elevates the slab of soil. In breaking over the back of the blade the soil falls away from the roots and enables the workmen to pick up the seedlings without difficulty. The blade can be adjusted to a depth of from 4 to 12 inches. This same frame is used for pruning 2-year-old seedlings in place, but for the pruning operation the wedge blade is removed and a thin, flat, steel blade is substituted. The thin blade severs the roots but disturbs the position of the seedlings only slightly. (See p. 48 and fig. 25.)

Another Smith digger, with slight modifications, is used at Savenac nursery for lifting five rows of transplants simultaneously. It is lighter in construction throughout, because the work demanded of it in the transplants is not as heavy as in the solid mat of roots underneath the seed beds. Instead of the heavy, wedge-shaped blade

the transplant lifter has a thin, flat blade with fingers attached at the back to elevate and break up the slab of soil containing the trees. (Fig. 42.)

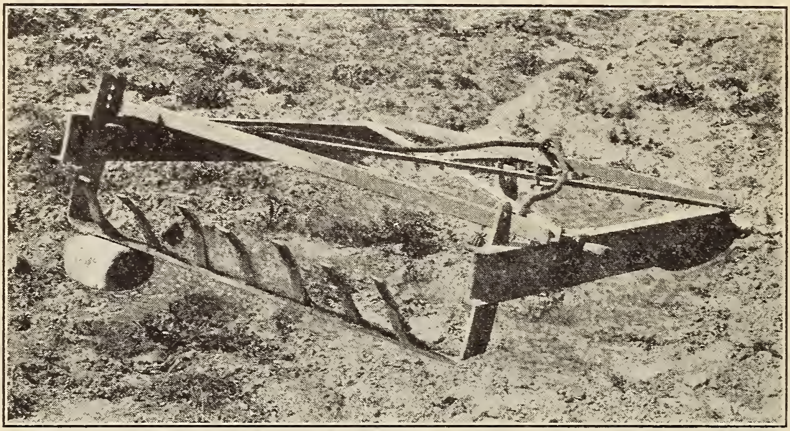

FIGURE 42.—The modified Smith tree digger used at Savenac nursery to lift five rows of transplants simultaneously

This implement is drawn by means of a cable passing through a block attached to the frame of the lifter and wound on a capstan at the end of the beds. One horse operates the capstan. With this arrangement the trees can be lifted from a 12-inch depth without

FIGURE 43.—Lifting shipping stock from seed beds with the Smith tree digger

any damage to the roots above that level. The implement moves slowly; consequently its progress can be stopped immediately when bulging in the surface of the bed or shifting of the frame warns that some obstruction underground lies in the path of the blade. Small stones are crowded above or below the blade, but niggerheads

and fragments of stump roots will lift the blade out of the ground and cause considerable damage to the stock if the progress of the implement is not immediately stopped.

Although a new set-up is necessary for each row of beds, it does not follow that a set of permanent deadmen is required across the end of the compartment. Suitable anchorage for the capstan is provided by a cable stretched the width of the compartment at the end of the rows. This is held in place by a substantial anchor at each end. The capstan and dead end of the tow line are quickly fastened to the transverse cable at each set-up.

PULLING, SORTING, AND BUNDLING NURSERY STOCK

The stock is inspected during the pulling and counting operation. Here the condition of the individual trees can be seen and the poor sorted from the good stock. Distorted forms, diseased plants, and trees with broken roots, or improper root development and plants too large for shipping should be culled. Undersized trees and trees with short roots, if occurring in large numbers, are again transplanted. Culling is not permitted at the planting camps; consequently any poor trees that slip by the shipping crew will be planted, thus entailing additional expense on trees having only a slight chance of surviving. For this reason it will not help matters to permit culls to get into the bundles and to increase the count to make up for the poor trees.

The trees are more easily pulled from the ground and less subject to injury if taken in clusters of two or more, than if pulled singly. A shake or light rap on the ground dislodges any clumps of soil. After the trees are out of the ground they can be separated and counted. Ordinarily, 100 trees make a convenient bunch; in large stock, 50. The trees should be kept in good order in the bunches so that later the roots can be evenly trimmed. A soft twine is preferred for tying the bunches, because hard waxed twine bruises the bark on the stems. The string should be tied in a loop knot that can be quickly undone by the planters without the aid of a knife. Proper lengths of string are cut beforehand, and each tree puller carries a supply of these, loosely fastened in his belt or suspenders in such a fashion that one string may be easily removed without disturbing the others. A convenient way to cut up this supply of string is to wind the string from the ball to two stakes set apart a distance equal to one-half the desired length of the string. When the string has been wound around 100 or so, a sharp knife cuts through all the string on the face of one stake.

The men should not be permitted to work close together when pulling the trees. Aside from the handicap of working in close quarters, the men will attempt to converse, and conversation can not be carried on if the counts of trees are to be accurate.

A very simple expedient makes it possible to get an accurate check on the work of each individual without necessitating continual inspection. By assigning to each man pulling trees string of a certain color with which to tie his bunches his work can be checked at any time. If one man uses red string, the foreman knows whenever he sees a bunch of trees tied with string of that color which man is

responsible for the work; and out in the planting camps where the trees are being planted a further check can be made on the quality of the trees found tied with the various colored strings. Such a system keeps the tree pullers on their guard. Also the man packing the trees can tally the output of each man by these colored strings, making it possible to put the operation on a piece-rate basis if desired. Twine of the proper size and texture is difficult to get in an assortment of a dozen distinctive colors, but white cotton twine can easily be dyed. Identification tags would answer the same purpose, but attaching these on each bunch entails an extra operation.

HEELING-IN

After tying a bunch of trees, the workman places it on the ground and pulls a handful of loose soil over the roots to protect them from drying out until the bunches are gathered up and packed. When stock is pulled more than a day in advance of packing it is necessary to heel-in the bunches in beds so that more care can be given to them. Heeling-in is very much like transplanting, except that bunches instead of individual trees are set in a trench. The roots are first pruned to the desired length, then dipped in water and the bunches set upright in a single row in the trench. Dirt is then sliced from the front wall of the trench and packed against the roots. A new trench is formed at the same time. Lath shade frames or brush is placed over the tops to reduce transpiration and the drying out of the soil. The heel-in beds should be kept moist but not wet. Poor drainage will cause mold to develop.

PRUNING THE ROOTS

The mechanical devices for lifting trees used at Savenac nursery permit the adjustment of the cutting blades so as to lift the trees from any desired depth. For this reason later pruning is largely unnecessary. A long pair of shears has been found most satisfactory when pruning is necessary, and for trimming off long straggling lateral roots that are missed by the blade of the tree lifter. Although a cleaver is used to chop off the roots of stock for transplanting, this does not prove satisfactory with the larger bunches of shipping stock because the trees in the center are pruned more severely than those on the outside of the bunches. With the shears the bunch of roots can be pruned round, resulting in more uniform pruning of all the trees in the bunch.

With some species, which have pronounced lateral root development and no taproot, such as Engelmann spruce and western red cedar, the roots seldom attain a length that requires pruning. Western white pine and western yellow pine are dug in such a way that the roots will be 8 inches long after they have been pruned and trimmed.

PUDDLING

It is considered injurious to swish the roots of the trees around in water before packing, because it washes away the soil particles adhering to the rootlets. If the roots are submerged in water they should be merely dipped in and not washed. It is best to have the packing material thoroughly soaked so that the roots will be watered

without being washed. Puddling is poor practice because the mud-thickened water used for a puddling mixture dries and seals the pores of the roots. Furthermore, when the roots are compressed in packing, the mud holds them in the form of a thin spear and the roots do not spring back to their natural spreading form when the tree is separated from the bundle for planting.

PACKING FOR SHIPMENT

Packing should be done by an experienced and thoroughly reliable man. Actual packing should not be done far in advance of shipping, but should be timed with the railroad schedules. If an order is canceled or shipment postponed after the stock is packed, the packages should be opened and the stock reset in the heel-in beds. The packed trees in a deferred shipment may not suffer, but the risk is unnecessary and should not be taken.

The trees should be packed in containers of a size that can be conveniently handled, for the larger the container the more costly the handling and the greater the breakage on the road. Most shipments are dispatched by express to shorten the time in transit. Express charges are comparatively high; therefore the deadweight (weight of packing material and container) should be as light as possible.

Sphagnum moss and cedar shingle tow (stringy sawdust from shingle manufacture) seem to be equally good for packing material. In the Northwest shingle tow can often be secured more cheaply than moss. At Savenac nursery it has been obtained locally at the cost of hauling.

In packing forest planting stock the roots of the bunches are overlapped in the center and the tops left exposed for ventilation. Wet packing material is spread over all sides of the stack of roots and between the layers of roots. No packing material is placed on the tops of the trees.

The Burlap Roll

The need for a tree container that could be conveniently packed on horses and mules to remote planting camps on the national forests was finally filled by the burlap roll. Figures 44 and 45 show this roll and the machine for making it.

The materials used in wrapping a roll of trees are a baling frame made from two strips of wood 1 by 2 by 22 inches, to which are stapled two 4½-foot lengths of wire (the two haves of a hay-bale tie); a strip of wrapping burlap 21 inches by 6 feet; a strip of butcher's manila wrapping paper of the same dimensions; and a twisting stick of the same dimension as one of the wooden strips of the baling frame. These are all prepared in large quantities in the tool shop on rainy days when the men can not work out of doors.

The baling frame is placed first in the tree packer with the loop ends of the wires hung over L hooks on the back well of the machine. The plain ends of the wires are bent back against the outside of the front side of the packer to be out of the way of the operator. The two strips of wood are on or near the bottom of the inside of the packer. The burlap is placed over the baling frame

with the ends draped over the front and back sides of the packer. The paper is placed over the burlap. When the roll is made the position of these materials becomes reversed so the paper is within the burlap to reduce evaporation in the bundle, and the baling frame outside the burlap to hold the bundle together.

After these materials are in place in the tree packer, wet shingle tow is spread on the paper in the bottom. Next, bunches of trees are placed on the shingle tow in a double tier; roots to the center and slightly overlapping, and tops to the ends of the tree packer. Alternating layers of wet shingle tow and bunches of trees are added, until the packer is full. Especial care is taken to place shingle tow between the trees and the paper on the sides as each layer is built up and on top of the last layer of trees, so that there

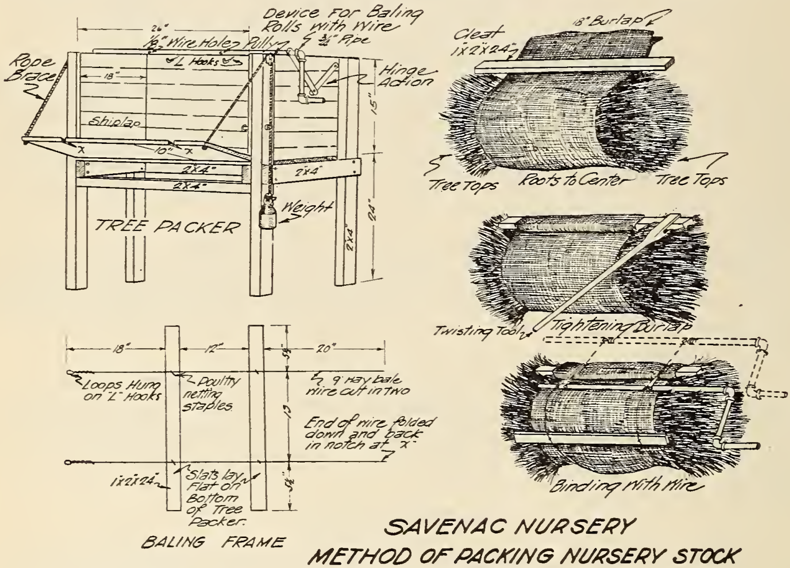

FIGURE 44.—Details of Savenac nursery method of packing nursery stock

will be an unbroken layer of shingle tow between the paper and the trees when the roll is bound together. When the tree packer is full, the ends of the paper are overlapped. The two ends of the burlap are caught together and wrapped around the loose twisting stick as far as possible without the aid of the twisting tool. This tool is then placed on one end of the stick (sometimes a twisting tool is used at each end) and the burlap drawn tight by turning the stick around once again.

The roll is now tight but will not remain so until bound by the wires of the baling frame. This is done by passing the plain ends of the wires through the loops on the opposite ends and into the holes on the bar of the crank lying on top of the packer. The bar is turned away from the operator until all of the slack wire is wound around the bar. The bar is then jerked toward the operator to kink the wire against the loop. The wires are then unwound from the bar, and each is clipped off about an inch from the kink. The ends

are twisted once around the wire, and the roll is securely fastened. The front side of the packer is hinged at the bottom so that the roll is easily removed. The completed bundle is then tagged, weighed, and placed under canvas to protect it from the sun and wind until shipped.

It is important that the twisting stick and the two strips on the baling frame protrude about 2 inches beyond the terminal buds that are exposed on both ends. Aside from giving rigidity to the rolls these strips, if made long enough, protect the buds when the rolls are handled in transit.

With the same material and packing machine the girth of these rolls can be made to vary so that the weight ranges from 50 to 100

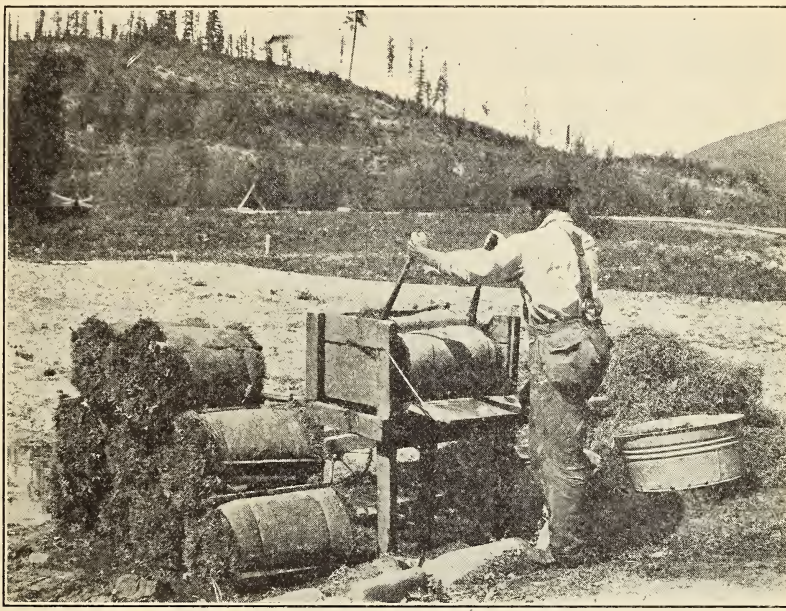

FIGURE 45.—Baling trees for shipment

pounds. Therefore the rolls can be put up in any weight desired by each planting camp to meet the maximum load for the pack animals. The average number of trees to a 75-pound roll is as follows:

Western white pine, 2–0	4,000
Western white pine, 1–2	3,500
Western yellow pine, 2–0	4,000
Western yellow pine, 1–2	2,000
Engelmann spruce, 2–2	4,000
Douglas fir, 2–1	3,500

This mode of packing has been used exclusively at Savenac nursery since 1915. Prior to that time wooden crates were used. Aside from being a more convenient container to transport on pack animals the burlap roll has proved to be a much cheaper method of packing trees and a means of reducing transportation costs 25 per cent.

The material in the burlap roll costs 14 cents. The burlap itself is the principal item, costing 11 cents. It can be used three times, how-

ever, and, being comparatively light, can be returned to the nursery at very small cost. Using the burlap three times brings down the cost of the roll for each shipment to 7 cents. Express charges on trees from the nursery to the planting camps average about $1.50 a hundred pounds. With the old method of packing, 25 per cent of the weight was in the crates. The material in a burlap roll weighs but 5 pounds to a 75-pound roll, costing only about 7 per cent of the express. A proportionate saving is made on transportation costs by pack train from the railroad to the planting camp.

The burlap rolls are as quickly packed as the crates. Trees in the burlap rolls remain in good condition in transit for as long as seven days.

Shipping Crates

A convenient style of shipping crate that was used at Savenac nursery before the burlap roll was adopted had the following specifications: Outside dimension, 24 by 14 by 24 inches; ends each made of two pieces ¾ by 4 by 24 inches, nailed to three cross pieces ¾ by 4 by 14 inches, providing two square openings 6 by 6 inches each, for ventilation. The sides, bottom, and top were made of solid ⅜-inch box boards.

Figure 46.—An order of 70,000 1–2 western yellow pine being loaded at Savenac nursery for a planting camp in Idaho

This crate cost 30 cents. About 4,000 white pine transplants (1–2 class) could be packed in it. Empty, the crate weighed 30 pounds, and packed for for shipment 100 to 110 pounds. Although these crates could be knocked down and returned to the nursery to be used a second time, the cost of transporting this heavy material by pack train and freight from the remote camps to the nursery was often as great as the cost of new material at the nursery. Also many of the crates were badly broken in handling or opening and could not be used a second time.

STORAGE OF STOCK

The growing season at Savenac nursery and that on the planting sites in the region which it serves so nearly coincide that there has been little need of retarding growth by storing the nursery stock. Ordinarily planting is not attempted in the spring on sites at high elevations which are not ready for planting when stock is ready to be removed from the nursery. Such sites are left for fall planting.

Only on a few occasions has it been necessary to hold back the growth of the stock for late planting.

STORAGE IN SNOW PITS

Snow-pit storage has been successful for holding back the growth of stock for late planting. This method is as follows: The stock is shipped to the planting site, where more suitable conditions are to be found for storing than at the nursery. A cold north slope on which there is still a heavy mantle of the winter's accumulation of snow is selected. Often natural depressions will be found that can be utilized for the pits. Otherwise holes must be dug. These should be about 5 feet deep. That depth is difficult to attain on mountain slopes where bed rock so commonly lies near the surface, unless the excavated material is used to build up the sides of the hole. The pit is then half filled with hard-packed snow over which is spread a thin mat of twigs or evergreen boughs. Then follows a layer of shingle tow or moss. On top of this are placed the bunches of trees in a single, compact layer, over which follows another layer of shingle tow and a covering of twigs. A shelter of canvas or boughs is erected over the pit, allowing about a foot of air space underneath. The young trees can be kept in a dormant state under such conditions for many weeks.

STORAGE OVER WINTER IN HEEL-IN BEDS

It often happens that fall planting terminates abruptly with the advent of winter, causing the cancellation of orders already prepared for shipment. The trees that have been pulled must be held at the nursery until the following spring. Such stock is ordinarily placed in heel-in beds in the following manner: The strings are untied and the trees of each bunch spread out in about a foot of trench. The strings are, however, left loosely around the trees in order that a recount will not be necessary when the trees are taken up in the spring. Care is taken that the tops of the trees do not touch the soil, otherwise molding will develop and the tops rot before spring. The danger of this mold is almost entirely eliminated by setting the trees in an upright position in the trench, and, after the trench has been filled with soil, placing shingle tow between the rows of tops. (Fig. 47.) A shelter of canvas or boughs is placed about a foot above the bed.

Through accidental circumstances at Savenac nursery, it has been recently found that frozen bunches of trees entirely covered with a heap of wet shingle tow, which later froze, were in perfect condition the following spring. This practice can not be recommended until equally good results are obtained by further experimentation.

INJURIES TO THE STOCK AND MEANS OF PREVENTING THEM

Savenac nursery has been extremely fortunate in having had no serious setbacks from insects and diseases, or other causes of damage. Consequently nursery practice at this place has developed comparatively little experience in combating the enemies common to most nurseries.

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However, it is startling to find that an accumulative loss of 50 per cent is often sustained between germination and shipment of the stock; yet none of the losses from any single cause are strikingly noticeable at the time they occur.

MECHANICAL INJURIES

Trampling on the new seed beds by children, by men and horses working in the compartments, and by cattle, dogs, and other animals that get into the nursery inclosure cause mechanical injuries to the trees. The damage that results is seldom justifiable, but generally is due to the carelessness of the workmen. The losses from cutting the corners of beds with vehicles, from moving implements about the compartments, and from dragging hose over newly sown seed beds,

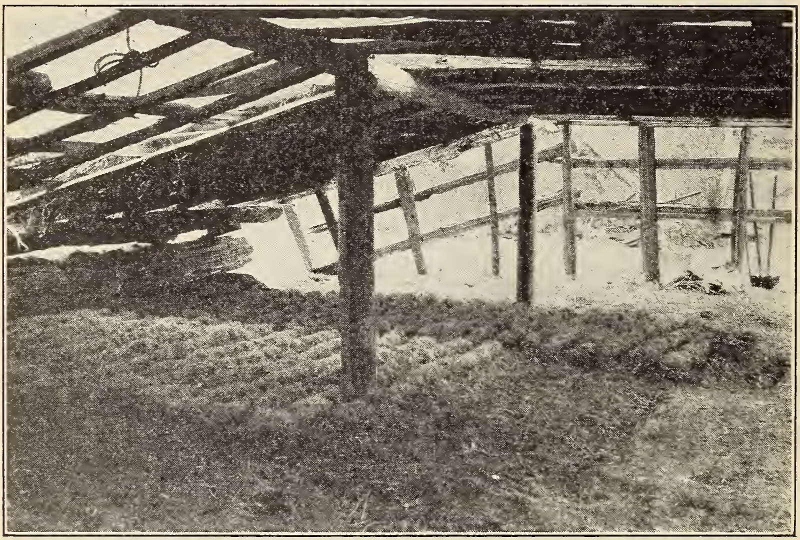

FIGURE 47.—A heel-in bed. The framework overhead is covered with canvas

thus disturbing the sand cover, are also caused by the carelessness of the workmen.

Oftentimes a greater direct loss is sustained through the use of mechanical devices than with the more painstaking hand methods. The extent of this loss depends to a certain degree upon the stage of development that the new method has reached. Stock that is lost in the early stages of experimentation can ordinarily be justified. Sometimes a new method entails a greater loss than the old one, but the operation is speeded up, or the quality of the stock that is not damaged is so greatly improved that the loss becomes of minor importance.

Further losses are sustained in weeding and culling and from washing away of the soil when irrigating.

DAMAGE DONE BY BIRDS

Most of the species of birds that feed on the seed in the newly sown beds are protected by law. Measures must be taken to protect

the beds rather than to get rid of the pilferers. Screen frames are efficient and practical for a small nursery, but for large nurseries the depreciation on the amount invested in screen frames may be far greater than the cost of hiring boys to scare away the birds. Shooting of blank cartridges and pounding of tin cans will frighten away the birds—only momentarily, however; so the noise making must be repeated at frequent intervals.

A foreign nurseryman abroad is reported to have conceived the idea of setting out a radio loud speaker in his nursery to frighten away the birds.

DAMAGE DONE BY RODENTS

CHIPMUNK DEPREDATIONS

The nursery is easily rid of chipmunks by shooting and sowing poisoned wheat (coated with sirup and strychnine) in the vicinity of their operations. Chipmunks do not damage growing stock. They feed upon the seed in the newly prepared beds, and they are especially active in the fall, pilfering fall-sown beds for their winter's supply of food.

ELIMINATING MICE

Mice seldom cause much damage, but, if necessary, can be easily trapped or poisoned.

DAMAGE DONE BY GOPHERS

Ground squirrels, locally known as gophers, cause the greatest annoyance through their burrowing in and near the irrigation ditches in early spring. Later, when water is turned into the ditches, much seeps out through these burrows and lowers the supply of water to such an extent that the holes must be located and plugged with sod. The animals are eliminated by shooting and trapping.

DAMAGE DONE BY MOLES

Pocket gophers, locally called moles, do much damage to the seed beds at Savenac nursery. They work under the snow, and therefore their work can not be observed until spring. Advancing from one root to another, they burrow just under the ground surface, leaving a ridge of earth on top. (Fig. 48.) These ridges cause more damage on new seed beds than the feeding done by the gophers. They can be trapped by compressing a recently made runway and setting a mole trap at that point. When the gopher finds the passage blocked, it tunnels through the obstruction and springs the trap. Carrots dipped in a strychnine sirup and placed in the runways have proved successful bait.

DAMAGE DONE BY INSECTS

CUTWORM INJURIES

Frequently cutworms migrate to the nursery beds from weedy patches and grasslands adjoining the nursery and for this reason the nursery should be located, if possible, some distance from such places. At Savenac nursery a ditch plowed around the seed-bed compartment has been effective in stopping such migrations. Where water can

be kept in such a ditch, the worms can not cross. If slope prevents the retention of a water barrier, a furrow may be plowed with the straight side next to the nursery, and a dust mulch maintained in it by some means such as by dragging a log along its length. The cutworms will not be able to climb up the steep side toward the nursery. If shallow postholes are sunk in the bottom of the furrow at intervals of about 20 feet, the worms will crawl along the furrow bottom and fall into such holes. Migration can also be prevented for a 2-day or 3-day period by scattering a strip of poisoned bait (described later) around the nursery instead of plowing a furrow; this serves the same purpose as a furrow and is sometimes more convenient.

Once the cutworms have gotten into the seed beds they feed on the tender shoots of newly germinating seedlings, cutting them off at or just below the surface. Unless the beds are closely watched the

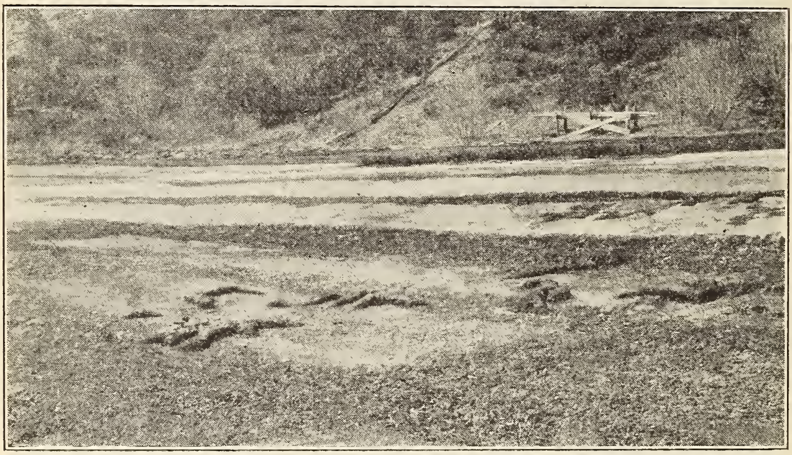

FIGURE 48.—" Mole " runways in seed beds. The damage is done in winter under the snow and is not realized until the snow disappears

damage may continue for a long time unnoticed. The cutworms do most of their feeding at night and burrow into the soil an inch or two during the day. If the infestation is confined to a known small area most of the cutworms can be unearthed in the daytime by raking the top inch or two of the soil with the fingers. For the species of cutworms which come above the ground to feed, a very effective control has been developed in the form of a poisoned-bran bait. This bait is made as follows: Wheat bran, 25 pounds; Paris green or crude arsenic, 1 pound; blackstrap molasses, 2 quarts; water, 15 to 20 quarts. Thoroughly mix the poison with the bran. This is important. Each particle of the bran must carry a little poison to get a good kill. Mix the sirup with the water and add this solution, a small quantity at a time, to the mixture of bran and poison, stirring slowly all the time. Large quantities of water added at one time will wash the poison from the bran, resulting in an uneven mixture. This bait, when scattered thinly over the infested area at the rate of about 10 pounds of wet bait per acre, often secures complete control in one night. Sometimes it may require two or three applications at 2-day intervals to rid the nursery entirely of the pest.

CAUTION.—Arsenic and Paris green are poisonous to animals. The poisoned bait must be carefully guarded before distribution because it is readily eaten by domestic animals, including fowls. After it has been scattered thinly there is no danger.

WHITE GRUBS

The larvæ of June beetles, commonly known as "white grubs," are a serious pest in some nurseries, particularly in the East, although they have not given much trouble at Savenac nursery. They are most injurious in newly broken grassland and considerable injury can be avoided by plowing the land for two years before using it for seed beds or transplants. The application of 3½ pounds of lead arsenate to 100 square feet of ground has proven very effective in the control of these insects in the East. The arsenic should be thoroughly worked into the ground before seeding or planting.

APHID INFESTATIONS

Infestations of aphids have caused no apparent damage to the stock at Savenac nursery.

DISEASES

DAMPING-OFF

Damping-off is the most serious of the diseases attacking coniferous nursery stock in most regions. There is considerable literature on the disease, both in connection with conifers and with truck crops. The old conception seems to have been that a parasite fungus killed the seedling by causing a local constriction of the stem at the soil surface. Hartley (*3*), however, points out that though several parasites apparently attack seedlings in this manner they also very frequently attack the seedlings in other ways, and that the cases which most closely agree with the older descriptions of damping-off are often not caused by parasites, and may occur under hot, dry conditions.

In a later publication, Hartley (*2*) p. 87 states:

> The most serious losses in conifers are ordinarily from the root-rot type of damping-off, occurring soon after the seedlings appear above ground and while the hypocotyls are still soft. Losses due to the killing of dormant or sprouting seed by parasites before the seedlings appear above the soil are also frequently serious, sometimes necessarily more so than the later types, as in extreme cases more than half of the seed of young seedlings are destroyed in this way. Damping-off due to infections of parts above the soil surface is serious only under extremely moist atmospheric conditions. The late type of damping-off, in which the roots are rotted after the stem becomes too rigid to be easily decayed, is ordinarily less important than the early types. Seedlings more than 2 months old are ordinarily able to recover from infections by the damping-off fungi. Even after the first month, seedlings with part of their root system killed often recover.
>
> The best control methods appear to be the disinfectant treatment of the seed-bed soil before or immediately after the seed is sown. Sulphuric acid has been found very useful for conifers, as they are apparently especially tolerant of acid treatment. No method has yet been worked out to a point at which all of its details are entirely satisfactory, though the acid treatment has now been in successful use for several years at some nurseries. At most nurseries, if the minimum effective quantity of acid is used, there is no need of any special precaution to prevent injury to the seedlings. It is not expected that any single treatment can be found that can be universally applied without change in details irrespective of differences in soil character and in fungous flora.

The stock at Savenac nursery has been infected with the damping-off disease at times over a period of 15 years, but its occurrence has been so infrequent that the cost of disinfecting the seed-bed soil after each sowing is not warranted. The treatment has been properly used at Savenac nursery on only a few occasions, and undoubtedly was beneficial, but the degree of benefit is uncertain because, unfortunately, no controls were installed. The disinfectant used at Savenac nursery, which is the one commonly used in coniferous forest-tree nurseries, is a solution of three-sixteenths of a fluid ounce of commercial sulphuric acid (93.5 per cent, specific gravity 1.835, 66° Baumé) and three-sixteenths of a gallon of water, applied to a square foot of seed beds within 24 hours after sowing. Within two days after the application the seed beds are thoroughly sprinkled, to wash the disinfectant well into the soil.

The same solution has proved injurious to the seedlings at Savenac nursery when applied after germination. A weaker solution has had no noticeable effect in checking the disease when applied after the seeds have started to germinate.

WHITE-PINE BLISTER RUST

White-pine blister rust has not made its appearance at Savenac nursery, but it has been found in the Northwest. Work is under way to eradicate all species of the alternate hosts of the genus Ribes, within a mile of the nursery. If this mile-wide safety zone can be kept free of the alternate hosts, it appears from studies carried on by the office of blister rust control of the Bureau of Plant Industry that the distance is too great for spores from other Ribes to be carried to the white pines in the nursery.

YELLOW-PINE BLISTER RUST

In 1915 the 2-year-old yellow-pine seedlings at Savenac nursery were generally infected with a fungus appearing as orange-colored eruptions of the fruiting bodies along the stems. Weir and Hubert (*1*) identify the fungus as *Peridermium filamentosum*. Galls and cankers of the same disease were found on larger trees of yellow pine and lodgepole pine (*Pinus murrayana*) growing on the forested slopes in the vicinity. Measures were immediately taken to control the disease. All visibly infected seedlings (about 4 per cent) were removed and burned. Steps were taken to remove branches containing the infection from the older trees in the vicinity of the nursery, and an attempt was made to eradicate the alternate host, Indian paintbrush (*Castilleja miniata*). This appeared to be an enormous task, and further work was abandoned. If there was any spread of the disease after its first appearance it was not noticeable. The following year it was not in evidence. It has appeared twice since 1915 at about 5-year intervals but on only a few plants. Each time the few infected seedlings found in the nursery beds were removed, and the loss of these was the only apparent damage. Among the large trees in the vicinity, many and perhaps all of which have passed through at least three epidemics of this disease, the injury does not seem to have caused serious losses.

PURPLE TOP

In 1915, another disease appeared in seedling beds of 1-year-old and 2-year-old white pines and yellow pines. The cause of this disease has not been determined, the term "purple top" being purely a local term. The infection occurred in the tips (the terminal bud and the top rosette of needles). The bud and uppermost needles first turned purple (hence the name) and later dried and became brown. The lower needles, however, survived, and only a comparatively few seedlings died, although many were temporarily deformed. A 4–4–40 Bordeaux-soap mixture was sprayed on the 1-year-old pines and a 5–5–50 mixture sprayed on the older trees.

The following year the disease was again apparent, but to a lesser degree and only in the yellow pines developing into the 2-year age-class.

One possible clue to the cause of this disease was brought out in a test of commercial fertilizers. All beds dressed with dried blood and bone meal in various amounts contained diseased plants, whereas a control strip of beds that had not been fertilized, extending through the compartment, showed no signs of the disease. Since this epidemic, no yellow pine beds that are sown to grow 2-year-old seedlings have been fertilized with blood or bone. The disease has not reappeared except possibly in a few doubtful instances of isolated seedlings.

BLIGHTS

SUN SCORCH

Sun scorch is in reality a drought injury. The damage is often patchy but more commonly affects individuals scattered throughout the beds. The plants so affected are the weaklings in the stand, having poor root-absorptive powers in proportion to the transpiring tops. The spindly suppressed seedlings in dense patches fall victims to the first drying out of the soil. Gravel pockets in the seed beds dry out more quickly than the surrounding denser soils, and on these the seedlings often succumb when general soil conditions are only slightly dry.

The needles of the affected seedlings first bleach to a pale, lifeless green, and then dry and turn straw color. The bleaching of the needles is the first sign of wilting in conifers, but even at this early warning the plant is beyond recovery.

Sun scorch is less common in transplants. The trees that are transplanted have been more or less selected by surviving drought conditions in the seed beds and by being passed in the culling at the time of transplanting. The loss occurring the first few months after transplanting, called "transplant loss," is sometimes attributed entirely to sun scorch, but ordinarily is due to mechanical injuries as well.

Unlike the seed-bed stock, transplants may recover after the needles begin to bleach. The cause of their bleaching is slightly different from drought. When the transplants are placed in a dry trench the soil absorbs the moisture quickly from the plants until an equilibrium is reached. This is called plasmolysis. As soon as more moisture is added to the soil by watering, the plant retrieves its lost moisture and revives.

Shading is often applied to reduce the loss from sun scorch. This practice is not recommended because, in order to save weaklings that would better be dropped at the start, the stronger seedlings are subjected to conditions that tend to weaken them. Frequently light watering and having plants of a predetermined satisfactory density spaced uniformly are the safest means of reducing loss from sun scorch.

WINTERKILLING

Transpiration during warm days in midwinter when the tops of the trees are exposed and the root systems are in frozen ground, and therefore unable to supply soil moisture to the transpiring tops, may cause death. In the West the warm winds known as chinooks produce such sudden warm periods in the midst of the coldest weather that not only small plants but even the largest forest trees are sometimes killed.

The needles of trees so affected quickly turn copper color. This color has led to the term " red belt," which is synonymous with winterkilling. Needles under the snow can not transpire; consequently large stock may suffer in some years when young trees, under a protectice covering of snow, are not injured at all. Conifers may lose practically all of their needles from winterkilling and, provided the buds are not injured, entirely recover.

Nonindigenous trees of the region, if from a warmer climate, are subject to winterkilling more than native species.

Mulch may be placed on the stock to protect it from winterkilling. However, if deep snow is to be expected, it is advisable to depend only on the snow for protection against winterkilling, with native stock in the nursery. More sensitive plants should be mulched.

FROST NIPPING

Frost nipping occurs in early fall and early spring when the stock has either continued rapid growth up to the time of a heavy frost or commenced spring growth and then encountered a heavy frost. In such instances the fast-growing, succulent parts of the plant are frozen, causing the water in the plant to crystallize and explode the cells. Precaution taken to prevent this damage in the fall is called " hardening-off." Ordinarily the measure consists in reducing artificial watering several weeks to a month before heavy frosts may be expected. The danger of light frost nipping, particularly in the spring, may be overcome by placing shade frames over the stock. The frames slightly retard spring growth.

Frost nipping kills back new growth and results in deformed tops, but rarely kills the plants.

NURSERY COSTS

The nursery cost-keeping system used by the Forest Service[14] classifies all nursery expenditures into 11 activities, called nursery projects. These costs are at the close of each year condensed into five projects of the major group and the cost per thousand trees in each determined.

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[14] UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE. NURSERY COST KEEPING. 1927. Multigraphed.

MAJOR PROJECTS

First-year seedlings.
Second-year seedlings.
First-year transplants. (This includes transplanting.)
Second-year transplants.
Stock distribution.

MINOR PROJECTS

Maintenance of soil fertility.
Mess.
Work animals and motor vehicles.
Administration.
General maintenance.
Permanent improvements and equipment.
Nonnursery charges.[15]

PROJECT COSTS

Major projects are charged with current costs of labor and materials used for those particular projects. The minor projects contain costs that are borne by all of the major projects in varying amounts, or that should be distributed over a period of years representing the life of their use, such as the maintenance of soil fertility and improvements.

The cost of meals—mess project—is actually a part of the laborers' wages and, therefore, is distributed as wages to the other projects. The costs of work animals and trucks are distributed to the major projects on a basis of time and mileage used on the various projects. Administration costs, which include the nurseryman's time, office expense, and similar overhead expense, are charged to the five major projects on a basis of labor hours worked on those projects. General maintenance is charged in the same way. Repair of screen frames and transplant tools and similar maintenance is charged directly to the major projects concerned.

New construction and new pieces of equipment purchased during the year are added to a perpetual inventory. This inventory contains all such items in use at the nursery with depreciation of each extended over a period of years estimated to be its life. Transplant boards and screen frames are depreciated over a 10-year period; sprinkling hose over 5 years; buildings over 20 years; and all other items in like manner. These are grouped in project classes and all depreciation charged directly to the projects using those items. For instance, depreciation on screen frames is charged to first-year seedlings; the sprinkling systems to both first-year and second-year seedlings; and tree lifters to stock distribution. Thus a large part of the list of improvements and equipment is accurately depreciated and charged directly to the five major projects. The depreciation on items of general use, or on those used in the minor projects, is apportioned to the major projects on a basis of labor hours worked on the major projects. That is, if twice as much labor goes into the care of first-year transplants as in first-year seedlings, the same proportion of depreciation of unclassified improvements is charged to those projects.

Ordinarily costs of fertilizing are charged currently to the major projects, but occasionally some extraordinary expense, such as liming

[15] It commonly happens that the nursery organization contributes to other national-forest activities, such as fire suppression and examination of plantations.

the whole nursery, may be incurred, in which case the cost is kept in a separate project and extended over a period of years. An equitable share of the cost is then charged to each project annually over that period.

TABLE 9.—*Savenac nursery project*[1] *costs, 1922–1926*

Year	Cost per thousand trees in major projects [2] of—						Apportionment from minor to major project costs [3]	Average wage paid per 8-hour day
	First-year seedlings	Second-year seedlings	Transplanting	First-year transplants	Second-year transplants	Stock distribution		
	Dollar	*Dollar*	*Dollar*	*Dollars*	*Dollars*	*Dollar*	*Dollar*	*Dollars*
1922	0.4250	0.2530	0.9100	0.8870	0.8410	0.6740	0.355	4.25
1923	.4520	.2349	.7883	1.0175	1.0474	.6940	.276	4.25
1924	.8358	.1691	.8401	.7210	.7319	.6766	.289	4.25
1925	.5402	.2208	.9254	.7101	.4479	.7416	.344	4.00
1926	.3863	.2752	.8880	.6796	.7424	.8113	.250	4.00
Average	.5279	.2306	.8704	.8031	.7621	.7195	.303	----------

[1] The new classification of nursery projects combines transplanting costs with the cost of caring for first-year transplants.
[2] The costs shown above include all current costs except cost of seed. The costs also include depreciation on equipment and improvements chargeable direct. This charge is small, averaging but a few cents per thousand for each project. Work animals, truck, and cost of mess are chargeable direct and therefore included in these costs.
[3] Includes nuseryman's time, general maintenance, and improvements and equipment in general use. The costs in this column represent overhead per thousand trees on each major project. To each major project cost is added the apportionment from minor projects to compute the total project cost per thousand trees. Thus the average charge against first-year seedlings becomes $0.8282.

OBJECT OF PROJECT COSTS

Final costs of stock produced at various Forest Service nurseries are of little value as a basis for comparing the efficiency of the work at each nursery because planting conditions prescribe raising certain classes of stock in one region, whereas in another region entirely different classes are desirable. It is obvious that seedling stock can be grown more cheaply than transplant stock, but it does not follow that all nurseries should grow seedling stock for forest planting. Project costs, as given for the Saranac nursery in Table 9, give a fair basis for comparison between two nurseries growing different classes of stock. For example: A nursery growing 2-year seedling stock has three major projects in common with nurseries growing 2–1 and 2–2 stock, namely, the cost of first-year and second-year seedlings and the cost of stock distribution. In addition all minor-project costs can be compared.

FINAL COST OF TREE PRODUCTION

The final cost of stock bears the cost per thousand of each project through which it passes in the nursery cycle, with its share of minor-project charges. Take, for example, a block of yellow pine grown as 1–2 stock. First there is the cost of the seed for this particular sowing. Then is added the average cost per thousand of first-year seedlings and an equitable amount of the minor-project charges. The second year this stock is charged with the project costs of transplanting and care of first-year transplants. Again the stock is charged with the apportionments from minor projects. The third

year the stock is charged with the project costs of second-year transplants and stock-distribution projects.

Nominal losses in the stock are borne by the particular block of stock in which those losses occur. If a whole block of stock is wiped out by some disease or fails to germinate, the expense incurred up to the time of the loss is distributed to the other stock in the nursery. Final costs at the Saranac nursery for the years 1922 to 1926, inclusive, are given in Table 10.

TABLE 10.—*Cost of stock per 1,000 trees by species and age classes,*[1] *Savenac nursery, 1922–1926*

Year	Pinus monticola				Pinus ponderosa				Picea Engelmanni		Pseudotsuga, taxifolio transplants	Thuja plicata, seedlings	Larix occidentalis, transplants
	2–0	3–0	1–2	2–2	2–0	3–0	1–2	2–2	Seedlings	Transplants			
1922	2.90	3.77	6.55	6.75	2.41	------	6.10	6.12	-------	-------	5.82	-------	-------
1923	3.62	3.57	6.45	6.25	1.78	------	6.42	5.04	3.27	13.29	9.00	5.47	-------
1924	4.62	4.72	6.39	8.58	4.09	------	6.14	9.87	4.16	10.31	6.33	7.16	7.08
1925	6.06	4.00	6.65	------	------	3.20	6.82	------	4.46	9.16	-------	6.13	11.93
1926	4.06	------	6.00	7.51	2.73	3.28	4.44	7.12	6.93	8.65	5.80	4.00	-------
Average	4.25	4.01	6.41	7.27	2.75	3.24	5.98	7.04	4.70	10.35	6.74	5.69	9.50

[1] Includes all costs, from cost of seed to packing charges preparatory to shipment of the stock.

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